AUGUST 1941

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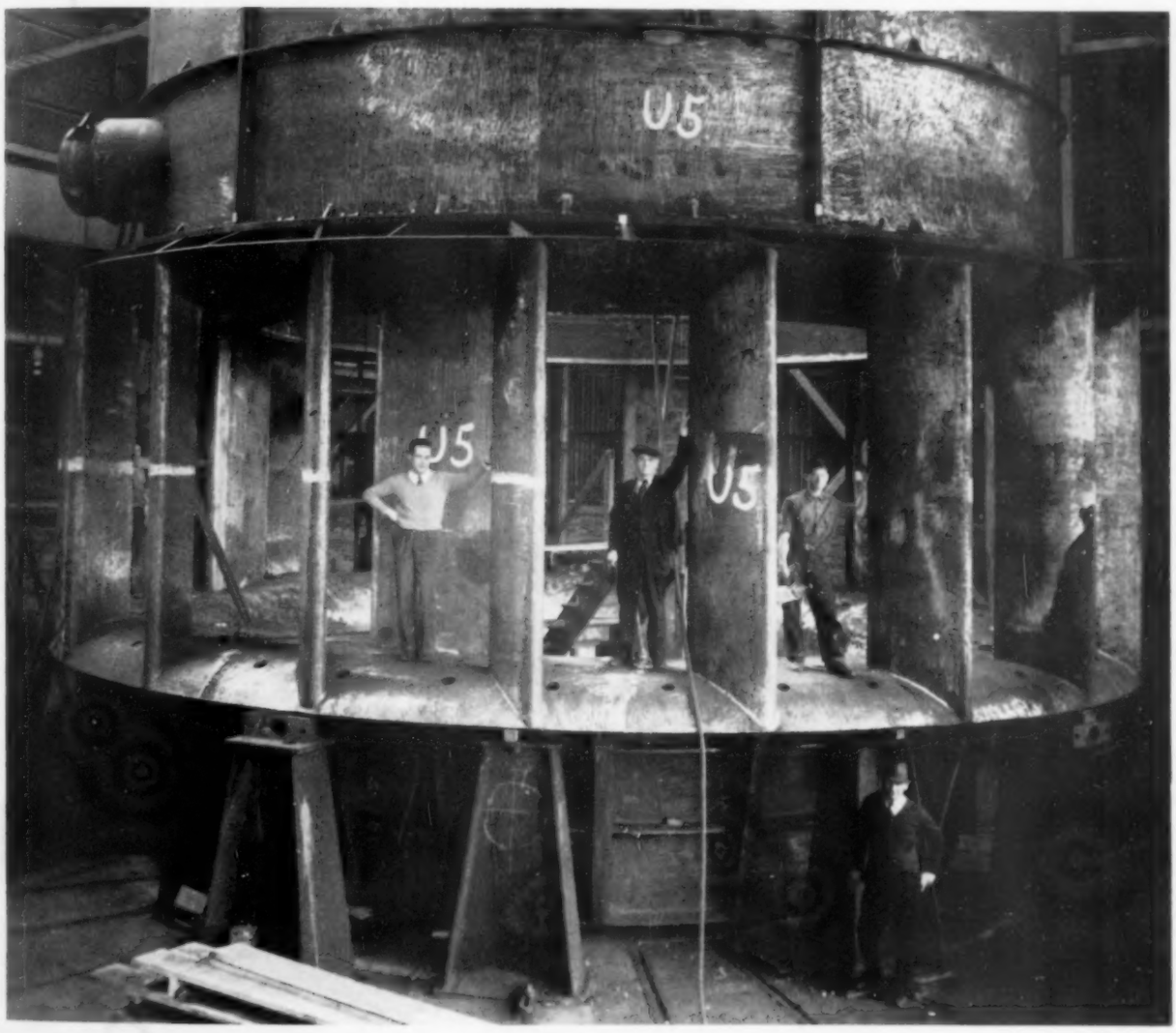
The WELDING Journal



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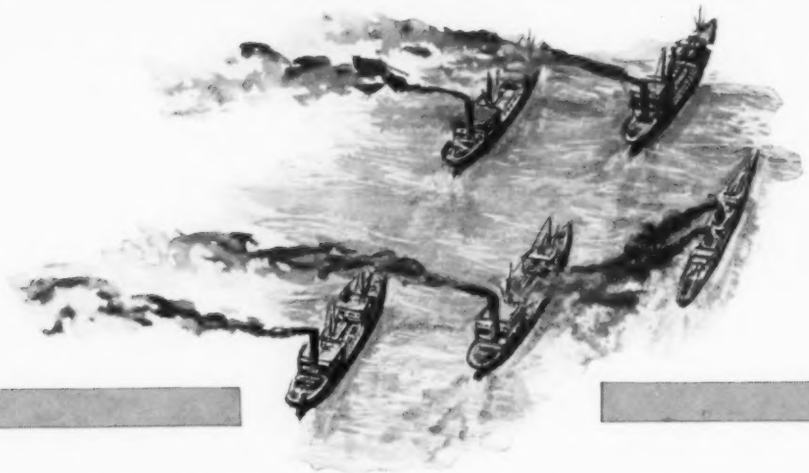

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"Spotweldability" of Aluminum Alloys*

By C. L. Hibert†

Introduction

SPOTWELDING of aluminum alloys is gradually developing from an experimental stage to a recognized production method of joining aircraft parts. Prior to this time of national emergency it was regarded as a necessary evil, mostly from the fear that someone would develop the process overnight and build a complete airplane for little cost. I believe that most companies are working to the desirable conclusion of welding a complete airplane of aluminum alloys, but this of course has not materialized, and parts that should be welded are neglected because of their relative unimportance.

This picture is rapidly changing and any manufacturing method that will save time is being applied, and instead of one or two spot-welding machines we find a battery of twenty-five to thirty machines. Some of these units are single purpose machines designed to do a certain job efficiently. This, of course, has necessitated a decided increase of personnel along with a training program to adapt men to the job.

Installations of many machines have presented a problem of power demand. The standard A.C. machine that the industry is familiar with requires an average of 150 kva. per machine for spotwelding of aluminum alloys, and multiplying this by the number of machines required for increased production it has often been found that the welding power demand exceeded the power demand of the entire machine tooling of the factory. In some instances the power required exceeded the source of supply, and special lines were installed. Due to this condition either machines or methods had to be changed. Fortunately two types of energy storage systems appeared on the market that only required approximately a 60 kw. demand, and the impedance to further development was solved. Unfortunately the manufacturers of spotwelding machines have only recently realized the importance of spotwelding in the aircraft industry and attempted to build suitable equipment to fulfil the need.

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† Consolidated Aircraft Corp., San Diego, Calif.

Table 1—Physical Properties and Chemical Composition of the Common Aluminum Alloys and Comparative Values for Other Metals

Alloy Designation	Spec. Gravity	% Copper Stand	Yield Strength, Lb./Sq. In.	Tensile Strength, Lb./Sq. In.	Shear Strength, Lb./Sq. In.	Per Cent of Alloying Element Aluminum Remainder			
						Copper	Manganese	Magnesium	Chromium
2SO	2.71	59	5,000	13,000	9,500	...	...	...	..
2SH	2.71	57	21,000	24,000	13,000	...	...	...	..
17SO	2.79	45	10,000	26,000	18,000	4.0	0.5	0.5	..
17ST	2.79	30	40,000	62,000	36,000	4.0	0.5	0.5	..
Al7ST	2.74	..	24,000	43,000	26,000	2.5	...	0.3	..
Alclad	..	..	.....	.....	.....	...	...	...	..
17ST	..	..	33,000	56,000	32,000	4.0	0.5	0.5	..
24SO	2.77	50	10,000	26,000	18,000	4.5	0.6	1.5	..
24ST	2.77	30	45,000	68,000	41,000	4.5	0.6	1.5	..
24SRT	2.77	30	55,000	70,000	42,000	4.5	0.6	1.5	..
Alclad	..	..	.....	.....	.....	...	...	...	..
24ST	..	..	41,000	62,000	40,000	4.5	0.6	1.5	..
Alclad	..	..	.....	.....	.....	...	...	...	..
24SRT	..	..	50,000	66,000	41,000	4.5	0.6	1.5	..
52SO	2.67	40	14,000	29,000	18,000	...	...	2.5	0.25
53ST	2.67	40	36,000	41,000	24,000	...	...	2.5	0.25
Mild steel	7.9	3–15	.....	75,000					
18-8	7.9	2.8	40,000	90,000					
18-8 C. R.	7.9	2.8	.....	up to 300,000					
Monel	8.8	4.0	35,000	85,000					
Hot worked	8.8	4.0	85,000	105,000					
Cold worked	8.8	4.0	150,000	175,000					
Brass	8.46	28.0	.....	45,000					
C. R.	8.46	28.0	.....	85,000					
Copper	8.94	100.0	.....	30,000					

NOTES: 1. No. 53S alloy has 0.07% silicon not shown on the table.
2. Values for aluminum alloys are according to specifications.
3. Values for other metals are for comparison only, subject to correction as to grade.

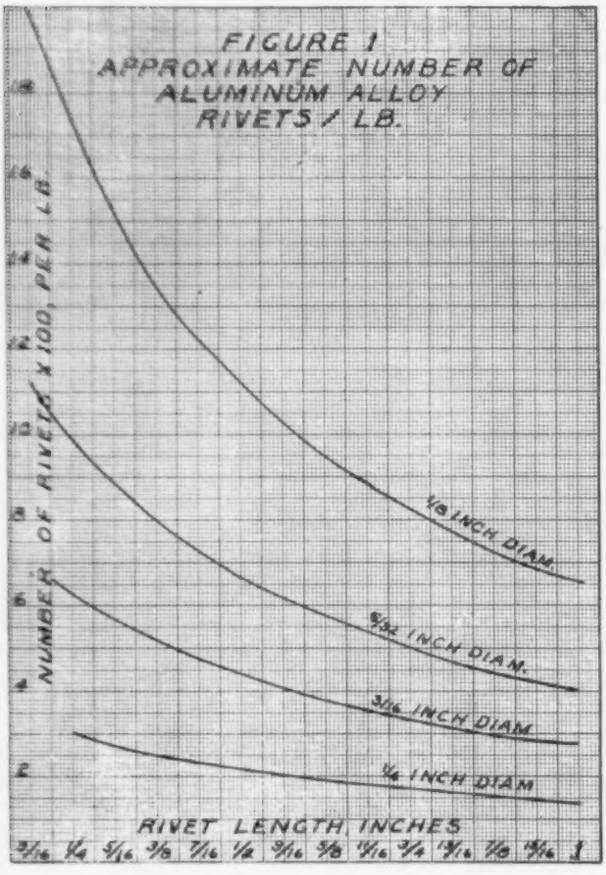


FIGURE 1
APPROXIMATE NUMBER OF ALUMINUM ALLOY RIVETS / LB.
NUMBER OF RIVETS X 100, PER LB.
1/8 INCH DIAM.
5/32 INCH DIAM.
3/16 INCH DIAM.
1/4 INCH DIAM.
RIVET LENGTH, INCHES
3/16 1/4 5/16 3/8 7/16 1/2 9/16 5/8 11/16 3/4 13/16 7/8 15/16 1

The necessary technique to operate the equipment had to be perfected by the aircraft manufacturers.

The general purpose of this article is to explain our problems and methods, to enable the various manufacturers of welding machines and experimental agencies to begin from the base that the aircraft industry has established.

"Spotweldability"

Spotweld operators gathering experience finally realized there is an indefinable something that makes each spotwelding job different. Perhaps one wonders why this process which has been used and worried over for so many years isn't an exact science. To begin with it is necessary to give the indefinable something a name and call it "Spotweldability" thus leaving a path open for further information on the subject. The conditions which are known to affect the "Spotweldability" of aluminum alloys are: chemical composition, surface conditions, conditions under which the welding is performed, the type of service to which the product is put, and the technical education and experience of the personnel employing the process.

Upon referring to Table 1 it will be noticed that the electrical conductivity of the aluminum alloys depends upon chemical composition and the temper condition. The higher percentage the conductivity, the less spotweldable the alloy. Soft-tempered or annealed material takes more heat and greater precautions than when the same material is in the hardened state, because the conductivity is comparatively greater in the soft materials. In other words, taking pure copper as 100% conductivity it would have 0% spotweldability. Of course this has to be said with reservations as copper, generally in an alloy form, has been spotwelded with difficulty.

Now let us consider stainless steel, with a conductivity of only 2.8%. Those familiar with spotwelding know that this is one of the easiest welded of any of the metals or the alloys.

Actually the weldability is a function of three resistances, namely: contact resistance between the electrodes and the sheet; specific resistance of the metal; and contact resistance between the two faying surfaces. But since resistance is a reciprocal of conductivity, and only clean work free of oxide coatings are welded in aircraft construction, it may be stated that for all practical purposes, per cent conductivity determines the "Spotweldability" of the alloy relative to chemical composition.

The conditions under which the welding is performed have a large bearing on the "Spotweldability" of the aluminum alloys, and by this is meant machine settings, size and shape of electrodes, edge distance and accessibility.

Machine settings are very important because improper results will be obtained on any type of equipment if improper settings are used. With the advent of condenser discharge method, closer control of machine settings is possible. On these machines the variables are

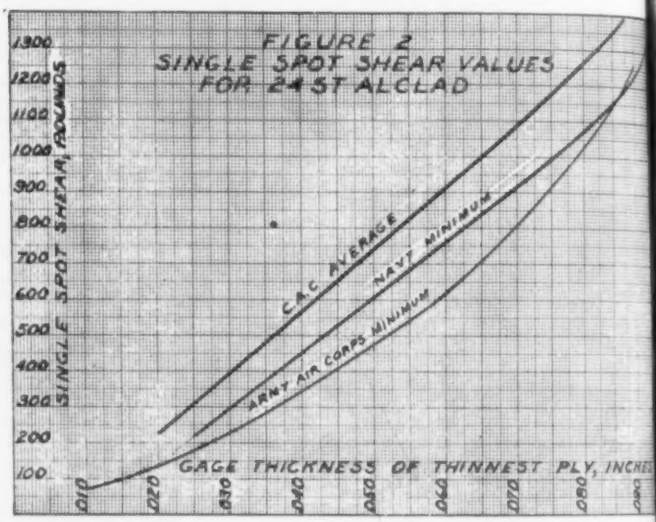
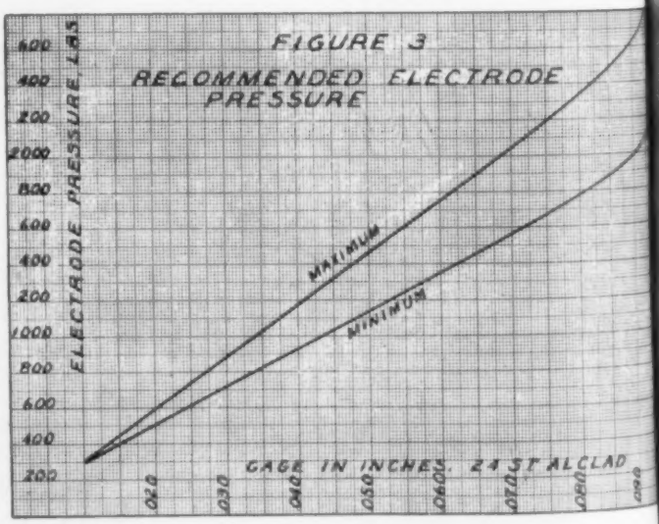


FIGURE 2
SINGLE SPOT SHEAR VALUES FOR 24 ST ALCLAD
SINGLE SPOT SHEAR, POUNDS
C.A.C. AVERAGE
NAVY MINIMUM
ARMY AIR CORPS MINIMUM
GAGE THICKNESS OF THINNEST PLY, INCHES

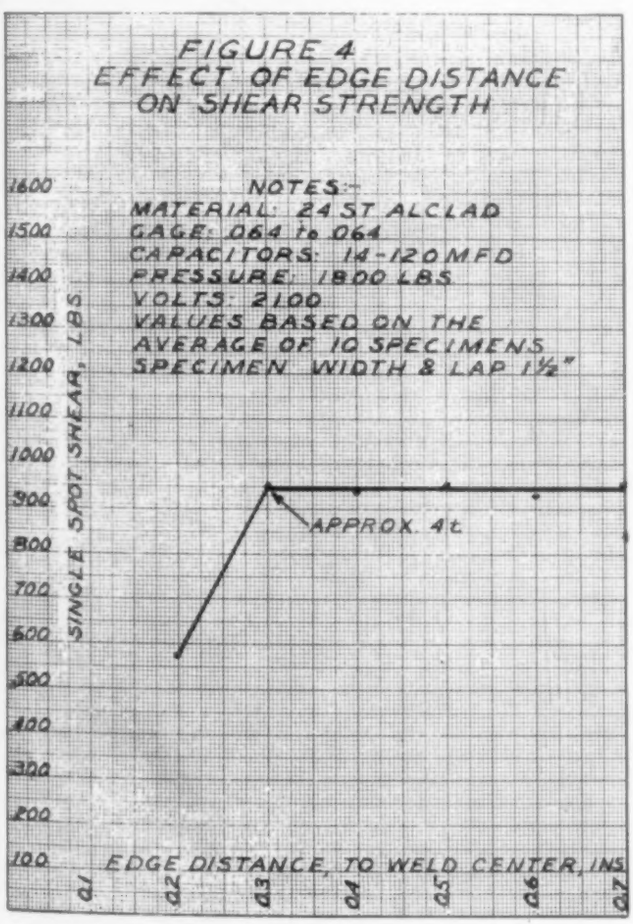


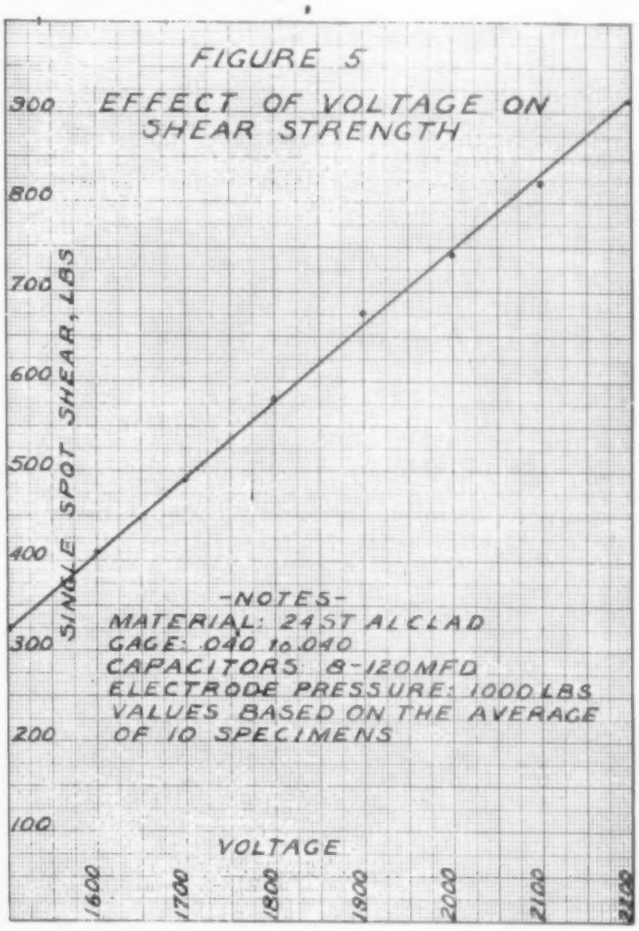
only three, namely, electrode pressure, voltage and capacity. The increase of time of discharge with increase of gage thickness is practically automatic with condenser discharge for as the capacity and voltage are increased for gage thickness, the length of discharge is consequently longer. The length of time it takes the current to discharge can be varied by changing the turn ratio. This is ordinarily fixed on the machine to handle certain gage limits and does not have to be set by the operator. Sufficient variation in discharge time can usually be accomplished by varying the number of capacitors.

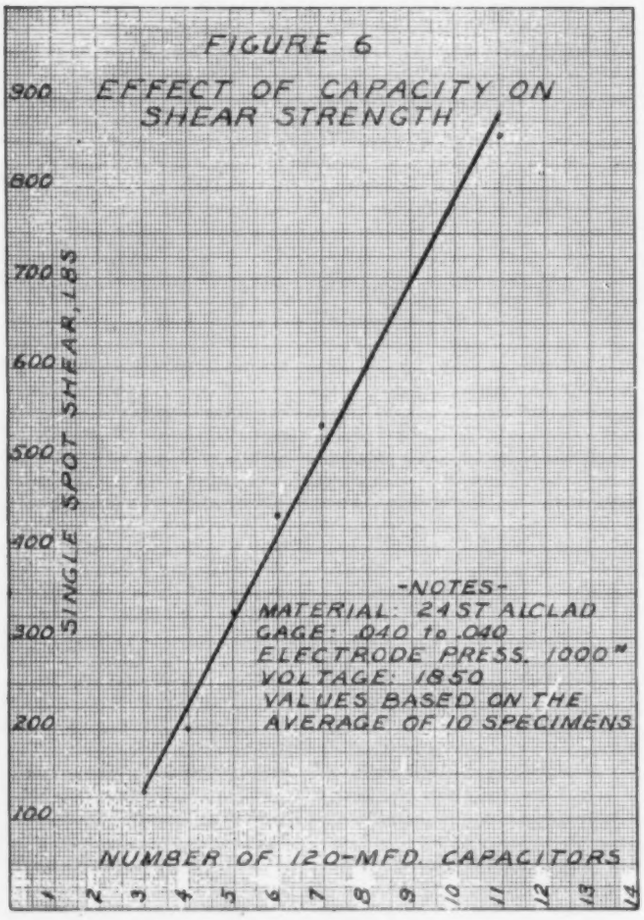
Pressure on Electrodes

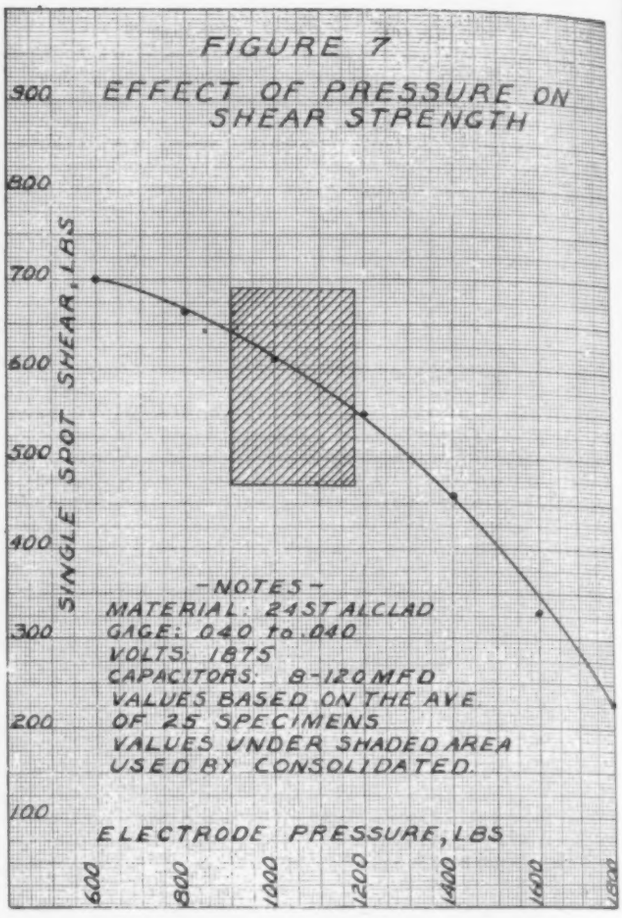
Aluminum alloys have a sharp transformation with practically no plastic range, and must be liquefied to coalesce. They have a characteristic of a relatively high solidification shrinkage. Such shrinkage takes place rather quickly as the metal changes from liquid to a solid state. The aluminum copper alloys, 17S and 24S, exhibit the greatest shrinkage. Unless some compensation is made for this reduction of volume a spotweld will exhibit defects of porosity and marginal cracks. The tendency in the past was to use low-pressure welding, because this gave higher strength welds with less heat. The recommended pressure value for 0.040 24ST alclad material was approximately 400 lb., using a 7° tip. When the weld was effected, under these conditions a splash of molten material was exuded. This type of weld exhibited porosity because the molten metal was not retained in the zone of fusion when it expanded. The sharp conical tip aided in the expulsion of molten metal because the maximum force was applied in the center of the weld zone and not evenly distributed over zone of fusion. High-pressure welds with less electrode contour exhibit a corona around the fused zone where actually the two faying surfaces have shown a tendency to become miscible at something less than the melting point, aiding the retention of the cast slug and preventing weld splatter.

Marginal cracks and porosity are a function of tip contour and electrode pressure. The higher the pressure and the flatter the tip, the less tendency of marginal cracks. Most manufacturers have stressed a recompression cycle to cut down weld porosity which has not been borne out by our experience. It is possible to produce good quality welds on standard A.C. equipment without this feature, if proper pressures and tip contour are used, whereas cracked welds will be obtained on any equipment if too low electrode pressure is applied. Perhaps a quick follow-up is the answer and therefore program control applied at the proper time may prove satisfactory. Of course, too high a welding pressure is impractical from a tooling standpoint, due to the deflection of the welding arms, which causes tip skidding. Extremely high pressures cause the weld zone to extrude slightly, leaving a gap of several thousandths of an inch between the sheets —another undesirable condition. Tip skidding will aggravate this as it tends to move the one sheet in relation to the other while the weld is taking place, causing warpage and misalignment. One can readily see it is rather difficult to discover the happy medium especially when many other variables will affect results. For this reason pressure is not specified as a positive value, enabling the operator to use some discretion according to tooling and other factors.









Surface Conditions

Consistent spotwelding depends a great deal on the proper cleaning treatment prior to spotwelding. The aluminum alloys have acquired film of aluminum oxide and this film is an insulator of very high melting point. If it is not removed, the oxide film results in excessive electrode pick-up and inclusions in the weld. Actually the film is too thin to measure in thickness or resistance. But it is very evident if an attempt is made to weld through it. Removal of the film at least makes surface conditions equal regardless of heat treatment or other treatment that would tend to increase the amount of the coating. There are, of course, exceptions such as in the case of the pure aluminum alloy 2S where it is advantageous to retain the coating in between the faying surface to increase the resistance of this high conductive alloy.

The removal of the oxide has presented quite a problem; older methods consisted of mechanically removing the film by wire brushing or by using abrasive paper on the surfaces. This, of course, was a slow process and caused various difficulties on thin materials especially with alclad coatings. When steel wool was used and was not blown off clean, the electromagnetic force at the electrodes gathered the steel wool and imbedded it in the weld. The anodizing treatment then burned out the imbedded particles, seriously etching the aluminum.

Army and Navy approval of the hydrofluoric acid etch simplified cleaning and lowered the cost of spotwelding. Present practice of cleaning the aluminum alloys is virtually as follows:

1. Pre-clean the material of vegetable dye, paint, dirt and oil with Oakite or Kellite aviation cleaner or similar solution.
2. Rinse in warm water to remove alkaline film of cleaning solution.
3. Etch entire assembly in 2 to 4% by volume of hydrofluoric acid and water in lead- or rubber-lined tank from thirty to sixty seconds.
4. Rinse immediately in cold running water to stop etching action.
5. Wipe over parts with sponge or wet rag to mechanically remove film left on by etch.
6. Dry off parts with an air blast.

There are several variations to the above procedure that will aid in getting a bright surface after etching. One or 2% of nitric acid added to the hydrofluoric acid will somewhat inhibit the etching action. This solution precipitates the copper constituent of the copper-bearing alloys as a black film which is easily removed with the wet rag. This is noticeable on the alclad alloys although they do have a coating of pure aluminum. In fact, the solution works best on the alclad alloys and is not practicable on the pure aluminum alloy such as 2S or the chromium alloys 52S or 53S and should not be used. This solution gives a semi-bright surface instead of dull white. If used it is necessary to have another etching tank to take care of the exceptions.

Another variation is to use the straight hydrofluoric acid etch and rinse in a 50% nitric acid solution. Here again this is only applicable to the copper-bearing alloys and should be avoided on all others. With nitric acid rinse it is not necessary to go over the parts mechanically to remove the precipitate as it is dissolved by the nitric acid. This process eliminates one operation and the alloy exceptions are rinsed in water.

The acid-etching solution should not be stored in wood tanks as the chemicals present in the wood might con-

taminate the acid, causing streaking and discolorations. Lead-lined steel tanks have been found the most practical for both the acid and water rinse. The etching solution will not work satisfactorily when first mixed unless activated by throwing in a quantity of dural chips or cuttings. It has been found that a large volume of etching solution works better and is easier to control.

Additions are made to the solution at regular intervals to control the acid concentration and it is not necessary to replace the entire solution. The acid tank needs to be cleaned out periodically when the accumulation of precipitate on the bottom of the tank interferes with the working area.

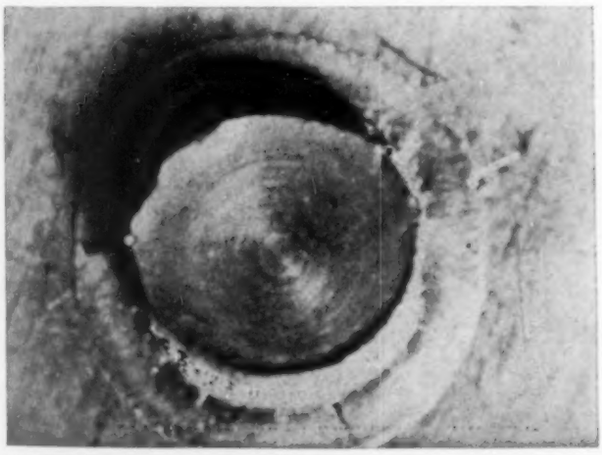
Constant exposure may cause skin irritations and it is best to equip operators with rubber boots, gloves and aprons, although the weak concentration of the acid does not appear dangerous to the health of the men.

Equipment

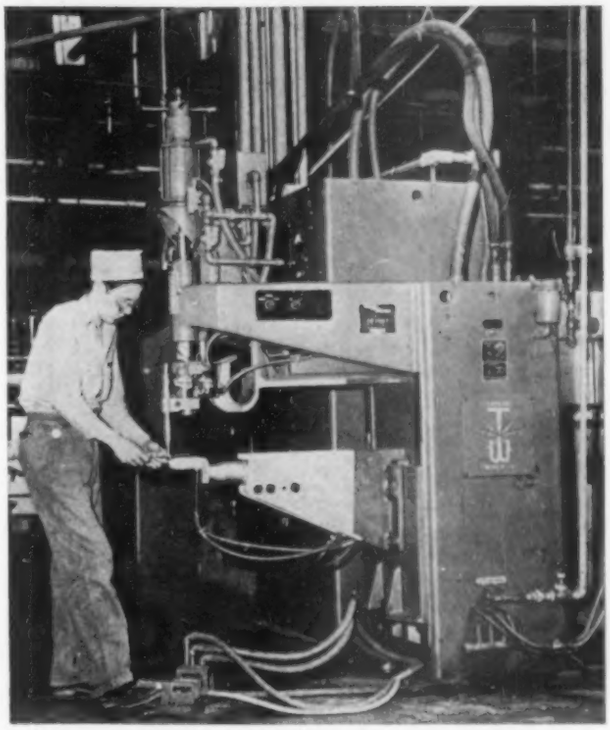
In considering new equipment it is best to order machines to straddle gage thickness, so that the most efficient machine is used in welding from a power speed and operation standpoint. In the past it has been the policy of the aircraft plants to specify machines capable of welding two pieces of $^1/_8$-in. aluminum alloy when most of the work to be welded is less than 0.064 in. in thickness. The fallacy of this is that machines designed for the heavy gages are physically out of proportion to do a good job on the light gages. The first cost of the equipment is much higher for a large machine than for a machine designed for the proper gage range. Cost of operation and maintenance are also higher and whether this increased cost can be justified is doubtful, as similar work could be done on much smaller equipment. No one would expect a large engine lathe to do a job that a small bench lathe could do.

At Consolidated Aircraft Corporation equipment has been ordered to weld the following: all stainless steel up to and including 0.032 aluminum alloy; 0.032 to 0.064 aluminum alloy and 0.064 to 0.128 aluminum alloy. The machines have a standard 36-in. throat with tooling interchangeable with any machine regardless of capacity.

Another mistake commonly made is to specify large throat depths and arm spacing when not entirely needed. Power required to weld a certain gage of aluminum alloy varies as to the square of the cross-sectional area between the welding arms. The larger this area the more inefficient the machine from a power standpoint. Actually a 36-in. throat depth can weld over 72 in. width, because usually half of the material can be welded from each side.



Macrophotograph of a Sheared Weld Showing the Corona Between the Faying Surfaces That Acts as a Gasket Sealing Off the Weld Zone and Preventing Weld Splatter. Typical of High Pressure Welds Made with Flat Contoured Tips on Condenser Discharge Equipment



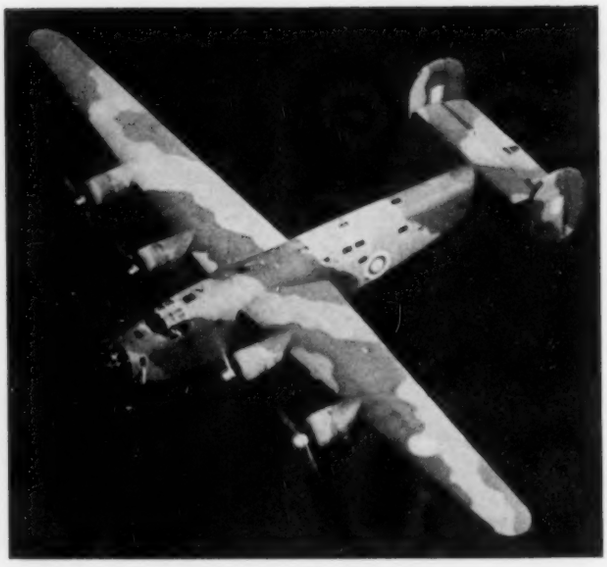
Condenser Discharge Equipment with the Consolidated Designed Lower Arm and Interchangeable Tooling. Control and Capacitor Panel on the Left-Hand Side of the Machine. All Operating Controls Are in Easy Reach of the Operator. Production Speeds of 2100 Welds per Hour Have Been Realized on This Equipment

The equipment required for the spotwelding of aluminum alloys consists of machines, electrodes and fixtures. There are numerous manufacturers who are able to supply dependable machines and it is rather difficult to make a choice. Generally the machine should include a lower arm mounted on a gib slide for vertical adjustment, the lower arm supporting a round copper bar for the electrode tooling with an "in" and "out" adjustment of a 12-in. minimum. This prevents the overhang of the upper horn, as the lower horn can be pushed back into the arm to compensate for various lengths of tools.

The upper horn should include a lateral adjustment in conjunction with a slight "in" and "out" adjustment to aid in the final alignment of the electrodes. If the tooling causes eccentricity of the electrode, alignment compensation of this condition can be accomplished by the lateral adjustment of the upper horn. Standard machines are usually supplied with two rigid vertical holders, which limit the equipment to flat work.

Machines should have adequate electrical power for the sheet thickness to be welded, and the electrode pressure gage should be calibrated to read in pounds load on the electrodes, rather than pounds per square inch of air pressure. The spotwelder should be equipped with adequate controlling and indicating devices to aid in making the proper settings. All controls should be within easy reach of the operator. The machine should be provided with a repeat operation switch and a retractable upper head assembly.

It has been found that the repeat operation increases production on straight runs and is less fatiguing for the operator. The retractable head enables the operator to



Consolidated B-24 Four Engined Bomber Has Many Spot-Welded Parts Including Cowling, Furnishings, Bomb Doors and Pilots Enclosure

clear obstructions such as angles and channels frequently encountered in aircraft production.

Electrodes and fixtures should be treated as separate tools for spotwelding of aluminum alloys. Fixtures are made of non-magnetic materials such as wood, micarta or scrap aluminum alloy casting. Fixtures may be classified under two general headings: welding fixtures and assembly fixtures. Welding fixtures are used for small parts, these parts being welded in the fixture. For large jobs where a welding fixture would be unwieldy, a checking or assembly fixture is used. Parts are set up in the assembly fixture and fastened with self-tapping screws to hold the alignment. A few spots are made in critical places and the job is again checked in the fixture before completion of the spotwelding.

Jobs that have straight sections without warped surfaces can be assembled without a fixture by holding the parts together with clamps or self-tapping screws. After welding, the screw holes are drilled to rivet size and riveted.

Size and Shape of Electrodes

It has been a standard practice of the aircraft industry to use a $^{5}/_{8}$-in. diameter electrode machined to a 7° cone tip on the welding end, for all machines and gage thickness up to 0.081 for aluminum alloys. Although the tip is machined to a 7° cone, it is not used for spotwelding with this sharp contour. The tip is slightly flattened when installed in the spotweld machine by dressing it with No. 150 emery cloth wrapped around a flat strip of micarta. With this dressing tool between the electrodes the upper head assembly of the welding machine is permitted to rest on the cleaning tool by force of gravity. The tips are then dressed by a rotary motion of the cleaning tool. The resultant emery dust is blown off the electrodes with an air blast and the final dressing is accomplished by using 7/0 sandpaper. To aid in developing a concentric slug several test welds are made for final shaping of the electrodes. The 7° cone tip with the above method of preparation is easily maintained by the operators and the welds appear to be flat with little surface indentation. After a finish treatment of paint the spotwelds are hardly noticeable. The rotary motion of the cleaning tool aids in keeping the contour because the cutting action depends on the peripheral speed of the cutting grains, and the farther out from the center the more cutting action.

Electrode tips with a flat machined on a 30° cone require too much technique in maintenance of their diameter and shape. Serious undercutting will result if they are improperly used. One reason for this is that a definite diameter flat must be used for each gage thickness welded. This, of course, would require numerous tips of various shapes, complicating tooling, machining and set-ups. The 7° cone tip accomplishes the same result, if prepared in the manner described, namely, a flat appearing weld without porosity.

Within certain limits the frequency of cleaning the electrodes on the machine, due to the pick-up of the aluminum alloy, is a function of tip contour, water cooling, secondary voltage, cleanliness of the material welded and welding pressure used. The less the tip contour and the higher the degree of the other functions results in less cleaning of the tips. Electrodes are removed from the machine for redressing on a lathe, only when changing to a different gage thickness, for if the cleaning of the electrodes is done properly they will last indefinitely for the same machine setting.

One would imagine that a highly polished tip would have less pick-up than one with a duller surface. With this thought in mind tips were polished to a mirror surface with crocus cloth and also with jewelers' rouge. In both cases the electrode pick-up was more severe than when common 7/0 sandpaper was used for redressing. The reason for this is not clear.

Considering the functions that determine the frequency of tip cleaning, the number of welds between cleans has jumped from 7 to 10 welds to 50 and 150 welds for the condenser discharge type machine. This has resulted in some exceptional runs of 2100 welds per hour for a 10-hour day on 0.025 gage material. This is twice as many as could possibly be run on standard A.C. equipment several years ago.

In the above discussion it is taken for granted that the electrode tips are water cooled sufficiently and they are in Group A, Class I or II according to the R. W. M. A.

Size and Accessibility

The size of the part and the accessibility have a large bearing on the "Spotweldability" of aluminum alloys. The fact to bear in mind is that the job has to be done on a fixed machine and it is necessary to take the work to the welder. At present portable equipment cannot be used for spotwelding aluminum alloys. This complicates the picture somewhat as large spotwelded assemblies have to be partially assembled in a fixture removed for spotwelding with a possibility of the part losing the alignment. Welding fixtures that are used to support the parts during the spotwelding have to be of lightweight construction, because they are manually supported. Most of the aluminum alloy spotwelding does not lend itself to automatic feeding or mechanical support. The reason for this is that the metal under the electrodes has to be aligned at right angles to the electrodes for best results, and a mechanical device does not have the advantage of the human touch. The work is supported by the helper or operator as one grips a billiard cue, not rigidly but lightly to permit the material to seek a level between the electrode tips.

A restricting factor on large parts is the time limit between etching and welding. The surface gradually acquires an oxide film with age, and if the welding cannot

be accomplished in a relatively short time, it is impossible to complete a satisfactory job.

To set any limits on the size and shape of parts that can be accommodated on spotwelding equipment is hardly possible as special equipment can be designed to reach relatively inaccessible places. It may be stated, from past experience, that the larger the physical dimensions of the part and the heavier the gages, the less positive the results.

Edge Distance

The most common error in designing spotweld parts is the failure to allow sufficient distance from the edge of the material to the center of the weld. As quoted by various authorities, the minimum allowable edge distance should be four times the sheet thickness of the thinnest ply in the joint. To be on the safe side, it is better to allow a greater factor than four. Especially is this true with the condenser discharge which can produce higher shear strength welds. On most drawings the correct edge distance is shown, but due to shop errors in trimming or bend radii, parts are often received by the spotwelding section with an added handicap of insufficient edge distance.

A certain amount of material is necessary to support the zone of fusion when the metal is liquid. The molten metal is contained under very high pressure calculated in pounds per square inch. If the solid metal boundary is not of sufficient section the weld will crack the outer edge of the material and spue out the molten metal between the plies. This condition results in low-strength welds. In designing parts it is imperative to recognize this very important factor.

Parts that do not fit perfectly or are buckled, affect the "Spotweldability" of aluminum alloys. The results of this condition are comparable to those found by insufficient edge distance. The lighter gage material will follow the contour of the heavier gage and distort the finished job. An objection often heard against spotwelding is that the welding warps the work. This is not true in the majority of cases and experience will show that if the parts fit prior to spotwelding they will not be distorted afterward.

For best results, welds should not be spaced too close together. Spacing can in many cases be the same or slightly less than a similar riveted type of construction. Spotweld spacing is usually approximated by eye, therefore only approximate spacing should be indicated on drawings. On non-structural parts from 0.040 to 0.064 gage a suggested spacing of 1 in. is ideal, and for lighter gages $^1/_2$-in. spacing should be standardized. Too close a spacing results in inferior welds caused by current loss from the shunting effect between the weld being made and adjacent welds in the joint.

Table 2—Shear Values and Recommended Settings for Condenser Discharge Equipment

Thickness, in.	Single Spot Shear Army, Min.	Navy, Min.	C. A. C. Ave.	Electrode Pressure Min.	Max.	Number of Capacitors 120 M. F. D.
0.016	110	....	....	....	....	1 or 2
0.020	140	....	225	500	600	2 or 3
0.025	180	220	310	610	720	4 or 5
0.032	250	310	430	730	920	5 or 6
0.040	345	430	565	910	1090	7 or 8
0.051	490	620	760	1130	1500	10 or 11
0.064	690	830	980	1420	1830	13 or 14
0.071	820	930	1100	1590	2030	15 or 16
0.081	1050	1080	1280	1800	2330	17 or 18

NOTES: 1. Values are based on experience and tests on Taylor-Winfield, "Hi-Wave" equipment.
2. Adjust voltage within limits of 1500 v. to 2800 v. to obtain single spot shear strength.
3. Gage thickness is based on thinnest ply in the joint. Pressure, voltage and shear value should be increased slightly with heavy to light gage combination.
4. Minimum pressure can be used in most cases.

Model 31 Flying Boat with Consolidated Davis Airfoil for Greater Efficiency at Cruising Speeds, and the Consolidated Fowler Flap Is Employed to Reduce Take-Off and Landing Speeds. Cowling Is Spotwelded in Lieu of Countersunk Rivets to Eliminate Drag

Stress distribution in the joint is contingent on spot spacing. This is a factor that will have to be investigated more thoroughly before stressed parts should be welded. The strength of a welded joint cannot be determined by multiplying the shear strength of a single weld by the number of welds. A riveted joint is made up of separate parts, and stresses are distributed by a slight yielding of the rivet or the material, but in the case of spotwelds in aluminum alloys the two plies are fused together with a cast slug with very little yielding for stress distribution. Therefore, it is possible to get a high stress concentration in but a single spot in the joint, which might start a progressive failure of the part. Of course, with a single row lap joint with adequate spacing, stress concentration is not serious, but care must be exercised in designing parts with several rows of welds. Resultant tension or torsional stress should be avoided on spotweld designs, as spotwelds in aluminum alloys are weak in tension and torsion.

Although combinations of three and four plies can be welded simultaneously, combinations of gages that vary widely should be avoided. No hard and fast rules can be given but a ratio of thick to thin greater than three to one is considered impractical. This is considering the alclad alloys. With those that do not have the alclad coatings the ratio of thin to thick is not a serious criterion.

Type of Service

The type of service to which the product is put bears a relationship to "Spotweldability." At present most of the spotwelding of aluminum alloys is limited to secondary structure and because aircraft is subject to corrosive atmospheres, only those alloys that are corrosion resistant may be welded. This further handicaps the use of spotwelding because the corrosion-resisting alloys are not

the most weldable. The alclad alloys are relatively more difficult to weld because of the soft coating of aluminum of high melting point and conductivity. When spotwelding was first introduced the plain alloys were used in the manufacture of aircraft, and specifying spotwelding necessitated a material change to alclad alloys, which severely restricted the use of spotwelding. Now practically all alclad material is used. The welding of stressed parts is somewhat restricted by the weldability of the alclad alloys.

Restriction of spotwelding to unstressed parts is not a question of physical strength, because sufficient strength can be achieved by proper design and fabrication. It is a known fact that a properly designed part can be made comparable to a similar riveted job in strength and serviceability. The determinative is whether the job can be assured of definite quality in production.

With multifarious conditions to control, some of which are beyond the reach of scientific approach, it is extremely difficult to predict results.

Perhaps a non-destructive testing device that could differentiate a good weld from a poor one would answer the always pertinent question, is it welded?

Personnel

The technical education and experience of the personnel determine whether the spotweld section functions with any degree of certainty. Of all the factors mentioned the human element is the most difficult to control. It is for this reason that it is impractical to calibrate machine settings rigidly, from laboratory samples. Each operator has his own manner of accomplishing the spotwelding, and where certain settings are designated for gage thickness, he may introduce variables of tooling and tip contour that would defeat the purpose of the setting.

In my opinion the spotweld operator may be compared to any other machine operator in so far as skill and common sense determine the quality of the work. At first glance, the spotwelding of aluminum alloys appears very simple to the layman, but there is more involved than merely pushing a foot switch. The control of the welding variables is useless, unless the equipment is operated by qualified personnel.

At least six months are required to train a prospective operator of sufficient ability to a point where one can expect confidence in his work. Usually a new man starts as a welder's helper and gradually he is permitted to weld small assemblies. As he gathers experience he is finally permitted to handle the machine he has been trained to operate. Quality is stressed rather than speed as production will be acquired with experience.

Each man is given a stamp with a number to identify his work. If mistakes are found they are immediately pointed out to the operator, enabling him to learn much quicker. In giving a man a stamp he at least takes more pride in his work, and is much more careful when he is held responsible for quality.

Personnel of the spotweld section includes the foreman, leadmen, operators and floor inspector. The foreman supervises personnel and maintains a liaison between the shop, engineering, planning and tool design. Leadmen supervise in a minor capacity, train new men and maintain production. The floor inspector checks the work when received and before it leaves the department. He also checks weld quality by shear and tearing tests on weld samples.

Conclusions

Of as great importance as the establishment of an initially satisfactory welding process is the maintenance of that process at a satisfactory level during the entire fabrication period. Since a visual inspection of spotwelds is entirely worthless, frequent check tests must be devised and resorted to by the spotweld section.

In the past it has been a general practice to conduct research on spotwelding by a laboratory procedure where all factors are carefully controlled, with the result that theory and practice are at a wide variance. Samples are provided with plenty of lap, electrode shape is carefully controlled, oversize electrodes are used and the easiest tooling set-up is on the machine; in other words, laboratory samples are welded under ideal conditions, whereas the actual job has to be made under conditions that are not ideal. Parts do not always fit perfectly, tooling is sometimes awkward, laps are too small to provide proper edge distance and a multiplicity of things may take place that alter circumstances.

Laboratory tests will not certify that a welding job is commercially practical. They might show that good welds can be effected under ideal conditions. Engineers should not be misled that primary structures should be welded, based on conclusions drawn from laboratory tests. In the final analysis the actual job will be done by the spotweld section under actual working conditions and one way to find out if a job is practical or not is to try to spotweld it by production methods.

In order to secure a liaison between the shop and the engineer the first piece of a new design should be made by the shop prior to the engineering release; changes and improvements could then be incorporated.

The advantage of spotwelds over rivets is primarily one of cost. If this differential of cost cannot be maintained, there is no advantage in spotwelding. Secondary advantages that can be realized are weight, appearance and elimination of drag caused by projecting rivet heads.

I trust I have not been too critical in expressing my opinions, but the tendency during an emergency is to flaunt established procedures and neglect cautions. If spotwelding of aluminum alloys is used with discretion, the developing of the process will proceed normally. If not, the process may suffer a recession that will seriously impede its rightful place in the aircraft industry.

TWENTY-SECOND ANNUAL MEETING

American Welding Society

IN CONJUNCTION WITH

NATIONAL METAL EXPOSITION

OCTOBER 19th to 24th, 1941

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High Pressure and High Temperature Piping*

By F. C. Fantz†

THIS paper is concerned with the use of welding in the fabrication of piping systems in general and high pressure and elevated temperature piping in particular. Completely welded power plant piping systems have been in use for more than fourteen years and high temperature and high pressure oil refining apparatus for over twenty-two years. When it is considered that welding equipment, material and technique of that time was very poor as compared to today, it is remarkable that such good results were obtained.

The increased use of carbon molybdenum materials in power plant piping made necessary by the higher working temperatures, has focused the attention of designers and engineers on this class of pipe welding. Good welds in carbon molybdenum pipe are no more difficult to produce than those in ordinary 0.10 to 0.20% carbon steel tubing. It is only the severe service to which the piping is subjected, and the consequent damage should a failure occur, that causes the designer to place so much emphasis on the making and checking of the welds. No mystery surrounds the making of a good weld and it is the writer's opinion that the use of welding and its apparent benefits are being retarded by too many different specifications and codes.

Some few years ago the AMERICAN WELDING SOCIETY appointed a committee to draft a standard method for determining the quality of a finished weld, also the ability of the welding operator. It was recognized by this committee that non-destructive testing, such as X-ray, etc., was impractical on piping work and that some other method must be used to determine the quality of the welds in question.[1,2] This committee then proceeded on the theory that a definite procedure of welding could be investigated by certain prescribed destructive tests and if the results proved equal to an established standard, it would follow that any subsequent welds made by the same procedure would meet the same degree of perfection. Time does not permit a discussion of the several methods of determining the adequacy of any particular procedure or the allowed variables entering into the procedure.[1] The particular welding procedure having been tested and approved, it was then necessary to test the operator as to his ability to apply that procedure. The chemical and physical properties of the deposited metal will be determined by the particular procedure used which, of course, includes the type of rod, and the operator is responsible only for the proper fusion and the degree of soundness of the finished weld. He can have no control over the physical and chemical properties except as they are affected by a lack of fusion and soundness.[4]

The result of the work of this committee was widely distributed to those interested and was adopted by the ASME Boiler Code Committee and the ASA Code for Pressure Piping as well as several state bodies and insurance and inspection companies.

It is expected that pipe welds made in compliance with the requirements of the ASA-B31 Code for Pressure Piping will be equal to the piping joined and insure a safe, dependable system. It is suggested, therefore, that purchasers of piping specify that all welding is to be done

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† Midwest Piping and Supply Co., Inc., St. Louis, Mo.

Fig. 1—Modern Welded Header with Valve Connections Flanged and Bolted

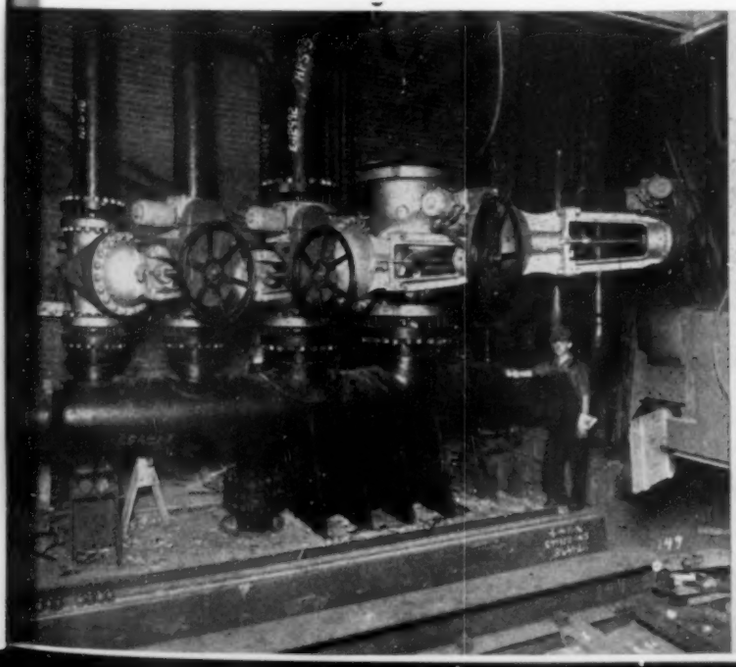
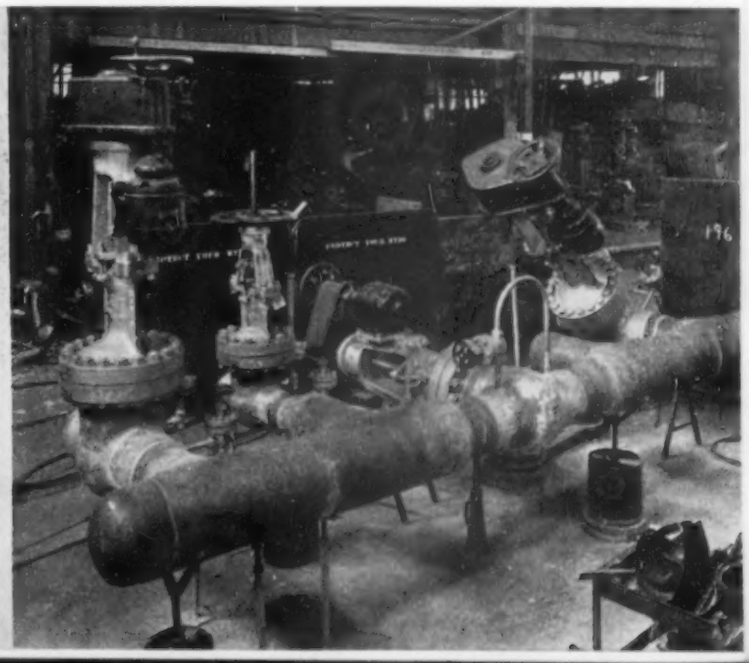


Fig. 2—Valves Designed for 1500-Lb. Working Pressure Welded in Place to Fabricated Headers



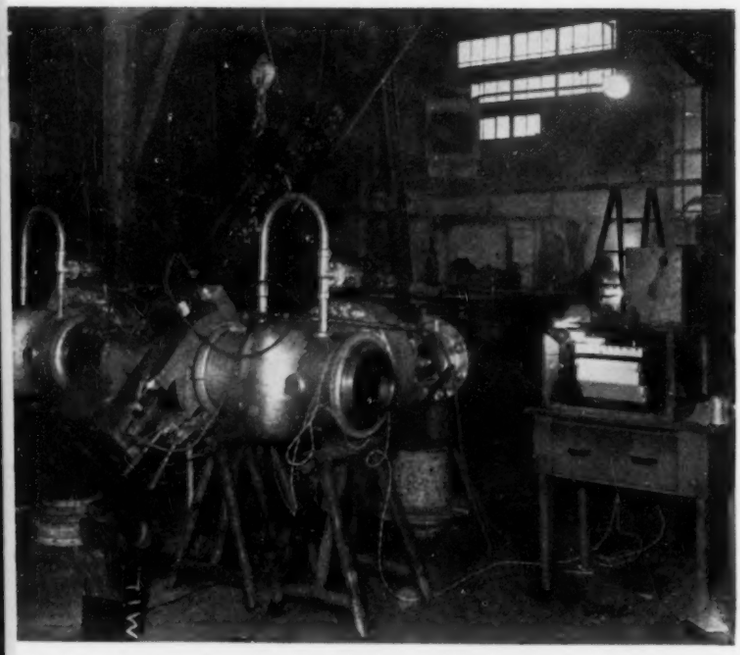


Fig. 3—Vertical Riser, Drip Pocket and Base with Valves Welded Integral

in accordance with the requirements of the ASA Code. The purchaser will then know what he is paying for and the contractor will know what he is contracting to furnish. It frequently happens that after a contractor has bid and obtained a job, he is required to furnish special tools and equipment and train welding operators in new methods and procedure in order to meet the specifications furnished by the purchaser or to meet the demands of the purchaser's inspectors. The resulting welds may have a better appearance and may also be of better quality than the material in the pipes joined; however, the purchaser would not expect or be willing to pay for the same accuracy, degree of finish or minute inspection of the parts of a reciprocating pump that are required and necessary on a turbine and generator.

As new alloys are made available for high pressure and high temperature piping, new methods of welding will be developed to suit the material and the conditions. This development should be accomplished in the shops and laboratories of the manufacturers of welding equipment and materials and the users of the welding process. The results of these tests and research should be submitted to the ASA Committee on Code for Pressure Piping for their consideration and adoption into the code, if found to meet the requirements. In this way, orderly progress will be made with the least expense and confusion.

Design and Fabricating Details

The development in the art of welding and the assurance of the integrity of welds have changed the appearance of the whole piping system. Flanged connections have been practically eliminated on high pressure and high temperature piping, resulting in less duplication of lines and a natural reduction in space requirements.

Valves are now welded directly to the header or in the line which assures a trouble-free, leak-proof assembly.

Figure 1 is a typical example of a modern header with the valve connections flanged and bolted.

Figure 2 shows 1500-lb. working pressure valves welded in place to fabricated headers of carbon moly material. The header in Fig. 2 was made from seamless tubing and the branch connections were reinforced with welding saddles.[4–8] In other instances they may be made from a hollow forging with sufficient increase in wall thickness over the schedule required, to compensate for the weakening caused by cutting the holes for the branch connections. These headers were annealed in a furnace and the valve connections welded and stress relieved after annealing. The welded joints were stress relieved with a portable furnace. Backing rings of a design described in a previous paper[4] were used, hence the wide overlay to the welds.

Special fittings or headers can now be made to meet almost any condition. Figure 3 shows a vertical riser, drip pocket and base with valves welded integral. A stress-relieving furnace is being used on one of the welded connections.

In Figs. 1 to 3 all valves have flanged and bolted bonnet connections. This type of construction is a possible source of leaks which would result in the shutdown of the system. Steps are being taken to eliminate these troubles, which in the case of high pressure and high temperature have been of considerable extent.

Valves are now being manufactured with bonnets welded[11] to the body casting as shown in Fig. 4. This valve is for a 12-inch main steam line with a 1500-lb. working pressure and designed to be welded directly into the line. The 6-inch diameter pot on the bottom is to collect sediment and to provide a means of inspecting the valve seats or parts should the occasion arise. The cap can be cut off, the valve cleaned out and inspected, and the cap rewelded without affecting the valve body.

Before attempting the welding of this valve the bonnet was redesigned to a dome shape and the location of the welded connection shifted somewhat to take advantage of the art of welding. Castings of the exact chemical and physical analysis, shape and dimensions were prepared and tests welds made to prove the adequacy of the design and welding procedure. The groove was of the U type with an included angle of 15° and 4 inches deep and it required 37 beads or layers to complete the weld, the first two beads being deposited with $^1/_8$-inch diameter rod using 26 volts and 120 amperes. The small rod was used to insure good fusion at the bottom of the groove. The next inch thickness of deposited metal was applied with $^3/_{16}$-inch rod using 32 volts and 255 amperes. The remaining deposit and overlay was accomplished with $^1/_4$-inch rod using 34 volts and 315 amperes. All deposits were with heavily coated rod by the metallic arc process using direct current. Means were provided to hold the parts in alignment during welding and to prevent the introduction of slag or foreign material to the inside of the valve.

Dimensions were taken before welding and after stress relieving to determine the amount of shrinkage. The longitudinal shrinkage was uniform at all points and showed a reduction in length of 0.172 inch. The reduction in diameter was 0.047 inch which was also uniform at all points.

The reason for the small reduction in diameter due to shrinkage may be attributed to the selection of the chemical analysis of the welding rod. As the area at the point of welding (being 4 inches thick) was far in excess of that required to hold the working pressure, a rod was selected that had less tensile strength and more ductility than the castings. This reduced the possibility of shrinkage strains or cracks caused by too sudden chilling of the deposited material.

It might be well to mention at this point that welding assemblies often fail because the engineer or designer has

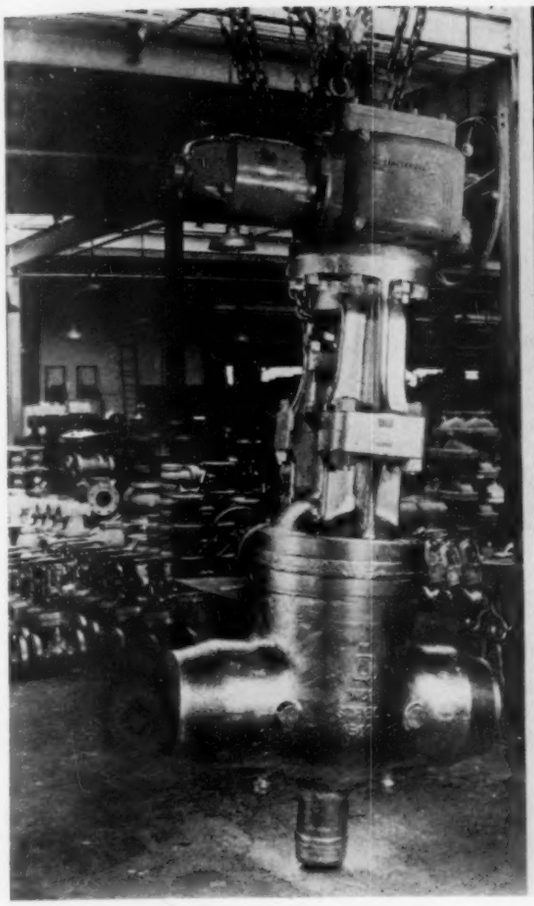


Fig. 4—Valve with Bonnet Welded to Body Casting

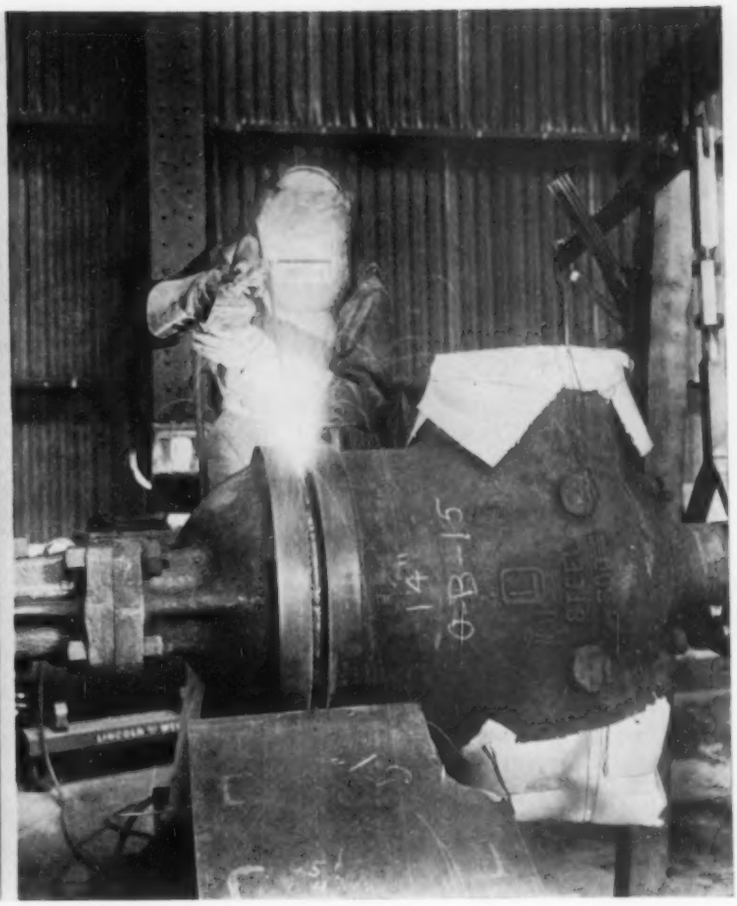


Fig. 5—Welding Bonnet to Casting

attempted to apply welding to a piece of equipment that was designed for other means of connection, such as bolting or riveting. Good welding can be accomplished only when the design and preparation for the weld take full advantage of the possibilities of welding and disregard all previous designs that do not conform to good welding practice.

Figure 5 is a view of the operator depositing metal in the groove of a 14-inch, 600-lb. valve of similar design. Revolving machines were provided so that the valve body and bonnet were rotated making possible the deposit of weld material in the downward position. A gas preheating burner was positioned under the shield shown in the foreground to maintain the temperature at approximately 500° F. during welding. The welding was not continuous and the valve was allowed to cool down overnight and reheated before welding was again started.

Figure 6 shows the application of the stress-relieving furnace to the valve bonnet connection.

Welding Fittings

Fittings with ends beveled for welding are now being manufactured from the various alloys suitable for welding and to match up with the schedule numbers of pipe and tubing. Dimensions of the popular types and sizes have recently been covered by the ASA Standard B-16-9-40. The materials entering into the manufacture of these fittings are covered by ASTM 234.

A welding fitting when welded to a pipe system becomes an integral part of that system, therefore the above-mentioned standards differ from the usual fitting standards in that the manufacturer is required to make physical tests to destruction to determine the adequacy of the design and the materials used. Each fitting offered for sale as having complied with these standards must be marked with the schedule number and the name of the manufacturer, as well as other markings, and be equal to the tubing of the same size and schedule number in so far as strength is concerned. It is the manufacturer's responsibility to provide the extra wall thickness or other means to compensate for the particular shape and, as in the case of welding tees, to compensate for the weakening effect of the branch opening.

The user can now select the make of fittings he desires with the assurance that it will be equal to the tubing joined and meet the safety requirements. The committees are still active and new types and sizes of fittings will be added to the standard as they are developed and the demand is sufficient to justify.

Figure 7 shows some recent additions to the line of fittings manufactured by our company that, it is thought, will be useful in the design of an all-welded pipe system. Reducing elbows are made in 90° only and at the present time in sizes from 2 to 12 inches, inclusive, with reductions to one size below $^1/_2$ of the large end, i.e., 6 x $2^1/_2$ or 12 x 5 reducing ells.

The lateral is made in 45° only, sizes $2^1/_2$ to 8 inches inclusive, with reductions to one size below $^1/_2$ of the run opening. The tees and crosses are made in almost any combination of straight and reducing openings.

The art of welding has progressed to a point where it is now possible and quite common to make practically

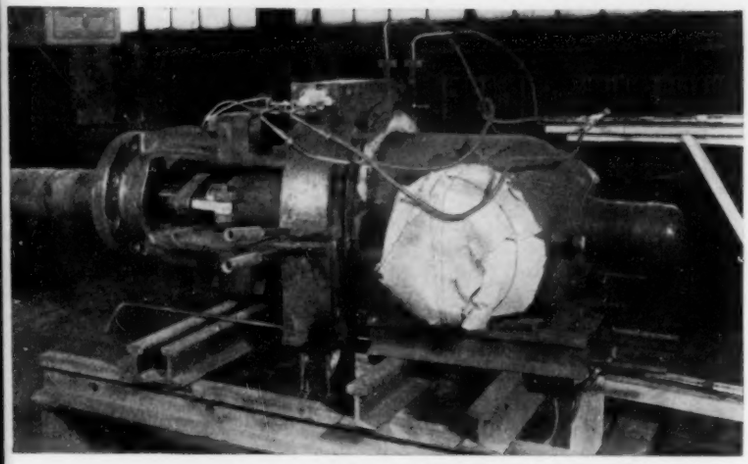


Fig. 6—Stress Relieving Valve Bonnet Connection

any type of special fitting by using combinations of manufactured welding fittings and sections of tubing cut to fit and assembled by welding.

Figures 8 and 9 are typical examples of what can be accomplished with standard welding fittings in either low or high pressure service. Figure 8 is an offset piece to cross over other lines and turn parallel to those lines. The use of bent pipe to form the various types of expansion bends is still considered the best practice for high pressure and high temperature installations.

Figure 9 is a combination of welded and flanged connections and shows how welding and welding fittings can be used to conserve space over the all-flanged and bolted construction.

Figure 10 is another assembly of a leak-proof, compact unit made possible by welding and welding fittings. This particular coil was made of high alloy material and full furnace annealed after the fabrication was completed. The coil was built up in the skid which was made of structural steel and also acted as a support for the coil during the heat treatment and shipment. It is now operating somewhere in England, presumably underground in a plant making aviation gasoline.

High pressure welding can be divided into two classes; namely, shop and field-fabricated. High quality welding can be accomplished in the field but completion time and the cost consideration demand that the pipe be fabricated as far as possible in well-equipped shops. If the job is of sufficient extent to justify the installation of a fabricating shop at the site of erection, it could then be considered economical to fabricate all the pipe in the field; however, very few jobs are large enough to justify the expense and most of the welding of high temperature and high pressure piping is done in shops of the established pipe fabricating companies.

Such welds as are made in the field[2, 11, 12] will be limited to tie-in welds to connect the pipe to equipment or to join fabricated units together that are too large to ship or handle in one piece.

After the layout of the piping system is agreed upon, the separate parts or units are designed and shop drawings made of each individual piece with identifying piece numbers, and any other engineering information necessary for fabrication. The shop is expected to execute the work and should not be expected to decide engineering problems.

Cutting and Shaping Machines

All plain end pipe for butt welds should be cut off and beveled for welding in the regular pipe-cutting machines. Special oxyacetylene cutting machines with mechanically guided torches are used for generating the curves for branch intersections and the shaping of plates for anchors, guides, reinforcement shapes, etc. Hand-

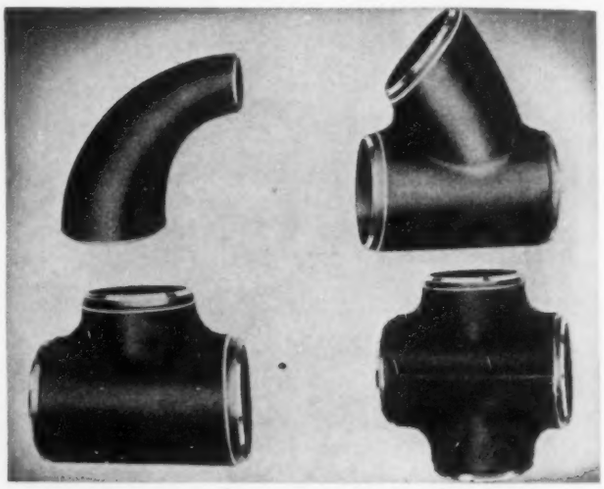


Fig. 7—Some Recent Fittings for Welding

manipulated cutting torches should not be used in pipe fabrication unless the parts to be welded are ground or otherwise made smooth. The small amount of scale left on the surface of a torch cut is not detrimental to the finished weld as the fluxing action of the rod coating is sufficient to clean the weld and prevent the formation of defects in the finished weld. Rough or grooved cuts are a sure cause of gas pockets and slag inclusion along the line of fusion.

Sketches are furnished the shop showing the cutting lengths, shape and type of bevel for each piece entering

Fig. 8—Offset Piece to Cross Other Lines

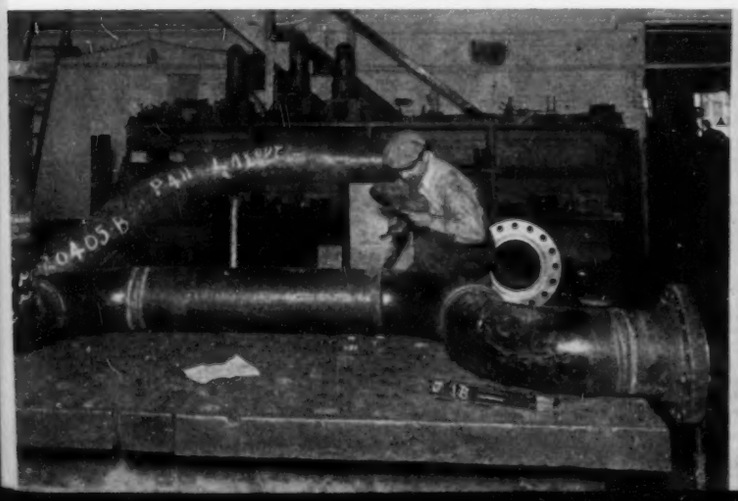
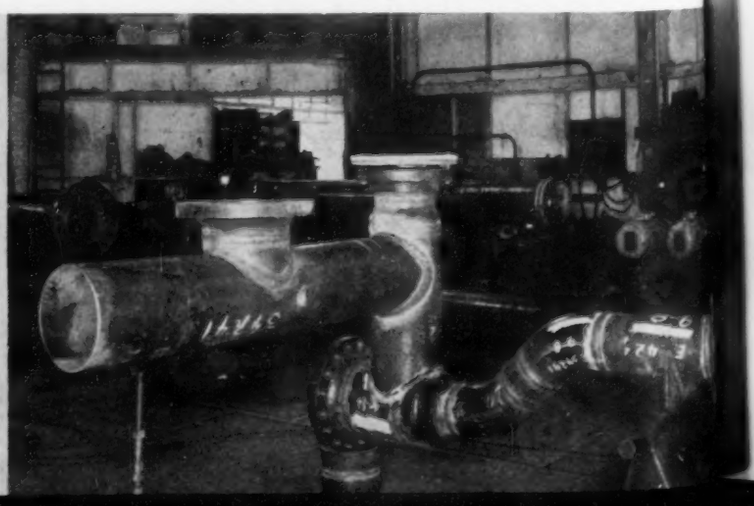


Fig. 9—Combination of Welded and Flanged Connections



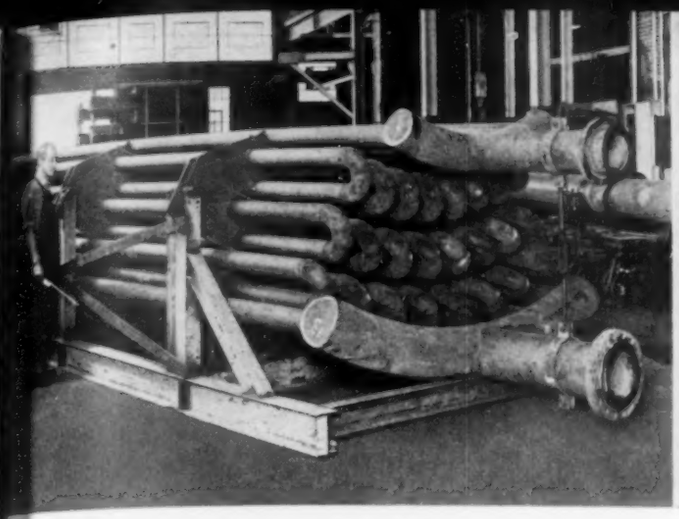


Fig. 10—A Compact Welded Assembly

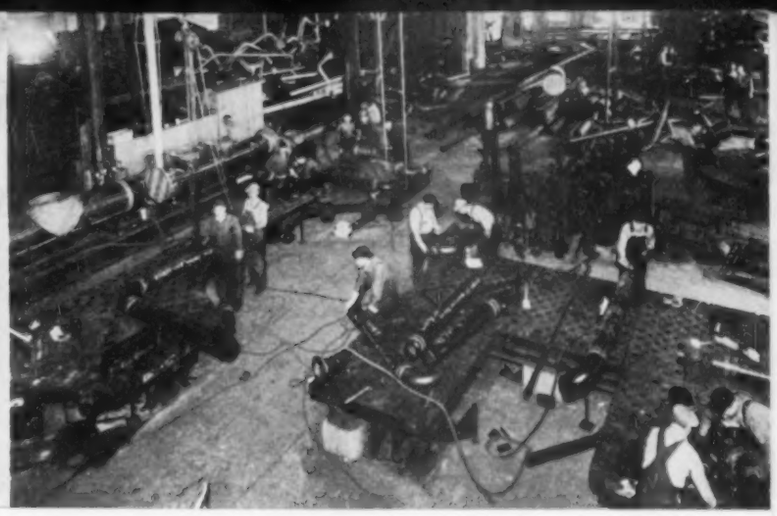


Fig. 11—Tables to Facilitate Welding

into the unit, together with the allowance for shrinkage, stretch in bending, etc., to enable the shop to finish the particular unit to the dimensions shown on the drawing.

Layout or Assembly Tables

This is one of the most important departments in the shop. The final dimensions and, to a large extent, the quality of the weld are determined here. Poor preparation and fit-up of the welding groove will make it difficult even for a good welder to produce quality welds and will require much more time. A good maxim for a shop would be, "The better the fit-up and preparation, the better the quality of the weld."

The tables shown in Fig. 11 are all machined on the face and set at the same height to accommodate long or complicated pieces on one or more tables. Sets of standard machined blocks from 1 inch to 18 inches are provided and by combining the various blocks any desired height can be obtained for the support of offset piping or to control the angle of connections or bends. A long machined bed with slidable V blocks is used for the set-up of straight pieces and the attachment of flanges and intersecting branches and connections. Special jacks, clamps, squares and other measuring and checking instruments are used to properly place the work.

The various pieces are lined up and tacked together preparatory to welding. Allowance for shrinkage is provided by spacing the proper distance apart. No attempt is made to allow for distortion during welding as this is corrected later in another department.

A particular pipe assembly may pass through this department several times; the piece shown in Fig. 12 was first assembled and welded in two separate pieces and then reassembled and tacked together for the final weld. In this way the smaller assemblies were welded with ease in small turning machines and the complete assembly welded in a large one with a consequent saving in time and cost.

Careful supervision and checking is necessary in order to prevent mistakes that would prove costly after welding is complete. The men are trained as layout men and are qualified to do tack welding. The tack welds are fused to the bottom of the groove or the inside diameter of the pipe and have a gradual taper from end to end to prevent slag inclusion in subsequent metal deposits. In our regular practice the tack welds are not removed during welding. If an attempt is made to remove these tacks, particularly in the case where a backing ring is used, it may result in distortion of the backing ring causing a defect in the weld at this point. Tests conducted in our shop on the finished weld specimens, cut through that portion that had been tack welded, have shown uniformly good results.

Turning and Positioning Machines

At least 98% of the welds made in our shops are handled in machines to revolve or position the work so that the weld is made in a flat or down position. At this time there is a shortage of experienced welders in certain sections of the country due to defense activities, and by the use of positioning machines less experienced men can be employed without lowering the quality of the finished product. These machines also enable an expert welder to produce welds in less time.

With the weld made in a down position, alternating current welding can be used to advantage with less arc-blow or magnetic disturbance. Higher heats and larger electrodes can be used.

The machines are powered with electric motors and the welding operator can control the speed as well as the direction of rotation with his foot, leaving his hands free to handle the welding and cleaning tools. The machines may be revolved at a faster rate for cleaning the welds. Air-scaling hammers and wire brushes are provided for removing the slag between the deposit of layers or beads. Small air-chipping hammers are used to remove any apparent defects in the deposited metal or any uneven deposit that may cause slag inclusion or air pockets in the next succeeding bead.

Figure 12 is a typical design of some forty machines used in our shops, ranging in capacity from a few pounds and small area up to five tons and pipe bends with a radius or leg of 12-foot length.

Preheating and Stress Relieving

The ASA Code for Pressure Piping calls for preheating to at least 400° F. for carbon steel material when the carbon content is in excess of 0.35%, the wall thickness one-half inch or greater, and on all carbon molybdenum welded joints. This preheating may be done by any suitable method provided that it is uniform and that the minimum temperature is maintained during the actual deposition of filler metal. Some engineers have insisted that the preheating should be maintained until the weld is completed and stress relieved. The writer is of the opinion that nothing is gained by holding the preheating temperature except during the actual welding and during the cleaning and chipping of any bead.

A weld may be allowed to cool to room temperature

at any time after metal equal to one-fourth of the thickness of the pipe wall has been deposited. It is assumed that room temperature would not be less than 50° F. When an incomplete weld has been allowed to cool it should be preheated before welding is again started. The principal advantage of preheating is to prevent a too sudden chilling of the deposited material which may cause minute cracks that could progress and cause leaks or ultimate failure of the joint. It should be remembered that a rather fast chilling of the molten puddle must take place or we would not be able to weld by the fusion process. Particularly is this true in the vertical and overhead positions.

If the molten puddle is allowed to become too large due to a rod of excessive diameter, or carrying the preheat at too high a temperature, the result will be a very coarse-grain structure with the possibility of shrinkage cracks and excessive locked-up stresses. The answer seems to be the use of relatively small diameter electrodes and a greater number of beads or passes to complete the weld, together with preheating until the first few beads have been deposited.

When backing rings are used on high carbon or alloy piping they should be made of a metal with a greater ductility than the parent metal. On carbon moly or 4–6 chrome piping, the ring could be made of mild steel which has no air-hardening tendency. In carbon moly welding the first bead could be deposited with a low carbon steel rod and the 4–6 chrome material using a 2% chrome rod. This method would reduce the tendency to produce minute cracks and would not impair the remaining strength of the joint.

Welds made in this way are showing very good results when subjected to the back bend test in a controlled jig.

In order to comply with the Code requirements it will be necessary if this practice is to be followed, to make requalification tests of the procedure.

Stress Relieving

The Code requires stress relieving in the following cases of welded joints:

1. On all carbon molybdenum welded joints where the wall thickness is $^1/_2$ inch and greater.
2. On all carbon steel welded joints having a carbon content in excess of 0.35%.
3. On all carbon steel welded joints where the pipe wall thickness is $^3/_4$ inch and greater.

The member having the highest carbon content or the greatest wall thickness adjacent to the weld shall govern, and when slip-on type flanges are attached to the pipe by fillet welding front and back, the wall thickness of the pipe shall govern. Stress relieving shall consist of slowly heating a circumferential band containing a weld in the center to a temperature of 1100 to 1250° F. and maintaining this temperature for a period based on one hour per inch of wall thickness for carbon steel and two hours per inch of wall thickness for carbon molybdenum; but in no case shall the holding time be less than one-half hour, and then the weld shall be allowed to cool in still air. The width of the circumferential band to be heated must be at least equal to twice the width of the welding groove, but in no case is it to be less than the width of the weld reinforcement.

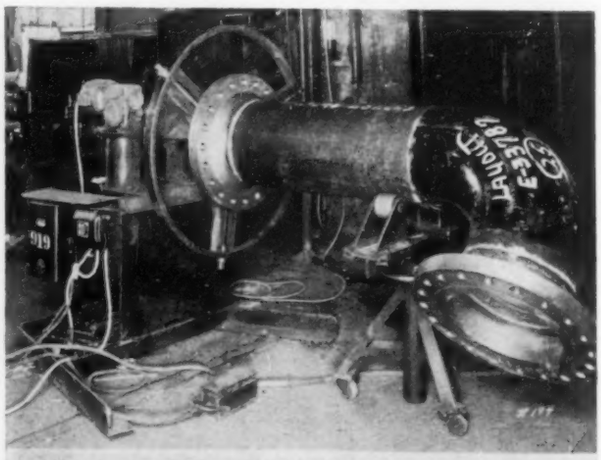
ASME Code for Power Boilers

Paragraph 108-3 of the ASME Code differs from the ASA and requires that the circumferential band have a minimum width of six times the plate thickness on each side of the welded joint. In such a manner the *entire* band shall be brought up to the temperature and held for the time specified for stress relieving. The writer believes that this paragraph was written for boiler sections and drums of large diameter and was not originally intended to apply to piping. It is thought that paragraph 108 should be changed to conform to the ASA B-31 when it is intended to apply to piping or possibly another paragraph inserted that does conform to ASA Code to cover pipe.

Where 12-inch pipe of $1^1/_4$-inch wall thickness is to be welded to a welding end valve, the width of the band would be 15 inches or $7^1/_2$ inches each side of the weld. If according to the Code the entire band 15 inches in length is to be heated to 1100 to 1200° F., the valve seats would be subjected to over 1000° F. unless some method was used to check the flow of heat into the main body of the valve. Naturally, any means of abruptly checking this heat transfer would set up additional stresses. Had the requirements of this paragraph been followed on the bonnet weld of the 12-inch valve shown in Fig. 6, it would require the heating of a band 24 inches on each side of the weld to 1100 to 1200° F. and the entire valve body would have been within this prescribed band and the valve seats and disks would have been brought to that temperature. Certainly this would be considered detrimental to the operation and life of the valve mechanism.

In the welding of pipe it has not been proved that the welding causes any detrimental effect in the parent metal adjacent to the weld for any such distance as covered by this paragraph of the ASME Code.

Fig. 12—Machine for Facilitating Assembly of Welded Parts



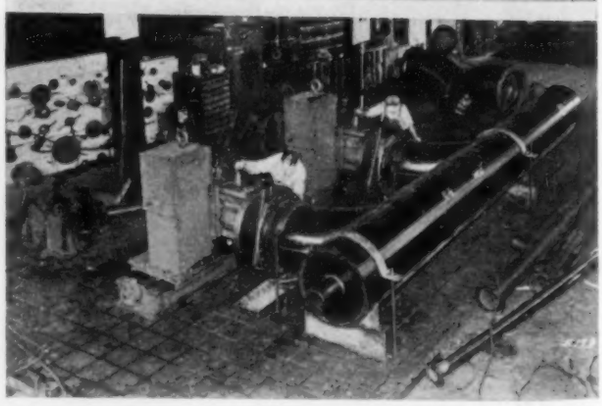


Fig. 13—Table or Bed for Lining-Up Large Assemblies

Stress relieving may be accomplished by any suitable method that will assure the control of the rate of heating and maintain the holding temperature without undue variation. A recording type pyrometer is recommended for use with stress-relieving equipment.

A number of welding engineers are of the opinion that with the proper preheating and welding technique, stress relieving is not needed and should not be made mandatory on low carbon and carbon molybdenum steel such as commonly used in piping.[3–6] The writer concurs in that opinion for the following reasons:

1. When the proper technique of welding is followed each succeeding bead or layer of deposited metal not only stress relieves but anneals and refines the grain structure of the preceding bead.
2. In pipe welding the parts joined are free to move longitudinally, preventing any detrimental locked-up stresses in that direction. Assuming this to be a fact, then it follows that the wide heated band called for in paragraph 108 of the Boiler Code is excessive.
3. The stresses that are locked up circumferentially are not considered detrimental to the strength of the joint; on the other hand, it should add strength to that particular section the same as would the shrinking of a band of steel to a cylinder or tube. The writer has never seen a crack across a pipe weld except those caused by extreme porosity or lack of fusion.

However, as long as there is a marked difference of opinion on this subject and until we have more data it may be well to stress relieve the joints made in high pressure and high temperature piping.

Figures 3 and 6 show the application of a portable preheating and stress-relieving furnace developed by our organization. This furnace uses as a fuel either natural gas and oxygen or propane and oxygen. We selected the oxygen instead of the compressed air as it was found that we could get the proper combustion in a much less space with the use of oxygen such as used in welding practice. These furnaces are shown for what they may be worth and as one way of obtaining the desired results.

There are several different methods in use, including the so-called electric induction[2–10] and resistance method[2] of preheating and stress relieving. We believe that the portable furnaces as shown have the advantage of being quick to install and remove for welding, and have found that the heat can be regulated and held to a very close degree. The two halves are hinged together and the burners are controlled by master valves in the gas and oxygen lines. Burner tips and mixing chambers are the standard oxyacetylene equipment hooked together by means of metallic flexible hose. It should be noted that acetylene is not to be used with this type of burner arrangement.

Headers and pipe assemblies are often completely fabricated and then placed in the furnace for stress relieving. On some of the alloys such as 4–6 chrome a closer regulated heat treatment is required rather than stress relieving. On 4–6 chrome material it might be well to mention that our practice in welding is to use atomic hydrogen in all cases where the work may be rotated so that the metal can be deposited from the top in a downward position. The atomic hydrogen flame provides the preheat necessary for this material and with heat treatment after welding we have found the physical character of the material to be ideal. A high degree of ductility with a very dense grain structure is possible.

This material may also be welded by the use of oxyacetylene and the metallic arc using due precaution as to the application of heat before welding and heat treatment after welding.

It should be pointed out that the atomic hydrogen method is more expensive than the other two mentioned, but with all items considered, such as the nature of the work and the effect should a failure occur, we believe that the added expense is justified. The remarks made previously as to the general handling, design and fabricating details will apply to this and other alloys.

Straightening and Squaring Equipment

During welding no attempt is made to prevent distortion and the finished piece is sent to the straightening table to be brought back to the dimensions shown on the shop drawings. Butt welds in pipe, flanges and fittings distort very little, if any. It is only on the intersection of one pipe or fitting with another or a series of nozzles that cause the distortion problem. Most of the straightening is done cold with the piece to be straightened held to the table by suitable pins or clamps and the power applied through a powerful winch by means of heavy ropes and sheave blocks. Squares, bevel protractors and straight edges are used to check alignment and dimensions. Rolls are sometimes used to straighten tubes and pipes that have been bent during heat treatment in a furnace.

Refacing Table and Portable Facing Machines

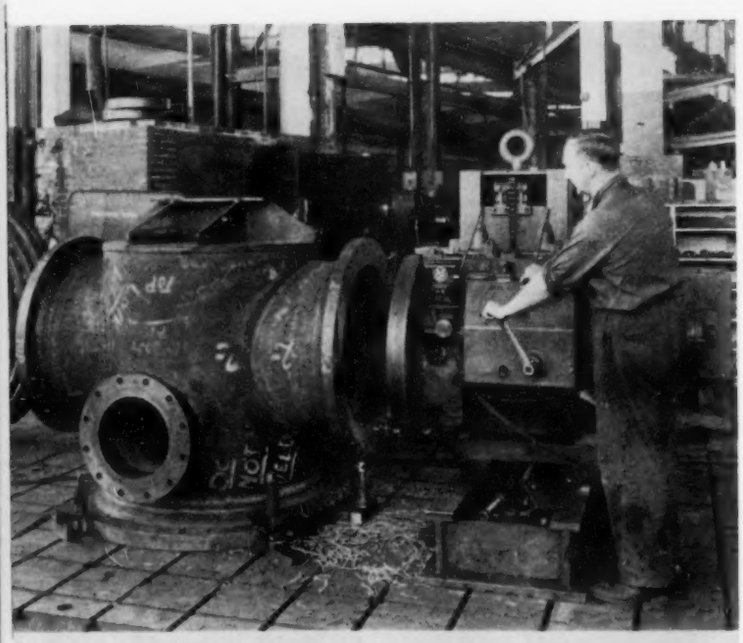
Flanged headers and heat-treated piping require refacing to either bring the faces parallel or to refinish the joint after scaling caused by heat treatment. Figure 13 shows a table or bed 15 x 40 foot dimensions with machined top and T slots every 12 inches along the surface. These T slots are cut at right angles to each other and are used to line up the portable facing machines with the work and to insure the same alignment when the machines are moved from one position to another. The main bed is made of sections keyed together, with jacks and hold-down bolts to adjust the table from time to time in order to keep it in a true plane. The machines can be positioned at any part of this bed and have adjustable movements in all directions. They are made of welded steel construction, very sturdy and will face from 0 to 40 inches in diameter. They are also equipped with boring bars for special boring operations.

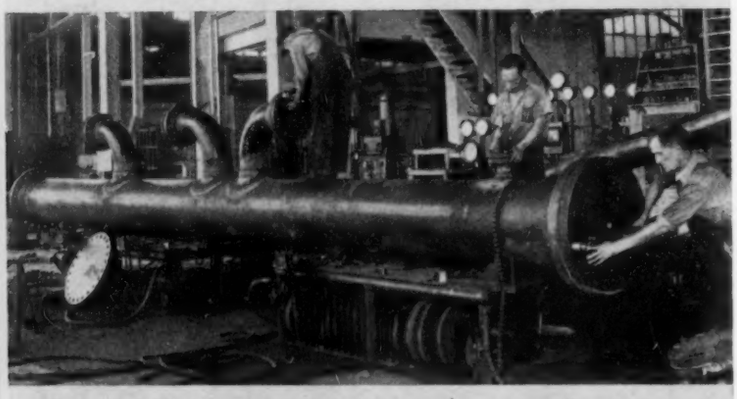
This table is also used for the close checking of headers and pipe assemblies. The work shown in this figure is a large low-pressure header and shows the application of two sections of welding elbows used as nozzle connections to insure a better flow condition. The machine is refacing the welded-on flanges to bring them in line with one another and parallel on the axis to the header. In the background is a long sweep tee fitting made from two 90 degree welding ells.

Figure 14 is a close-up of the machine facing a special low-pressure flanged fitting of welded construction.

Cleaning

During the progress of fabricating such as bending, shaping, welding, etc., some of the mill scale is loosened on the inside of the pipe and other scale and impurities are formed. This scale may become loose and cause serious damage to the valves and turbine blading, as well as other apparatus, and steps must be taken to remove anything that may become loose during the operation of the system. Sand blasting has been resorted to but it is a tedious job and there is some question about removing all of the sand before operation. In our shop





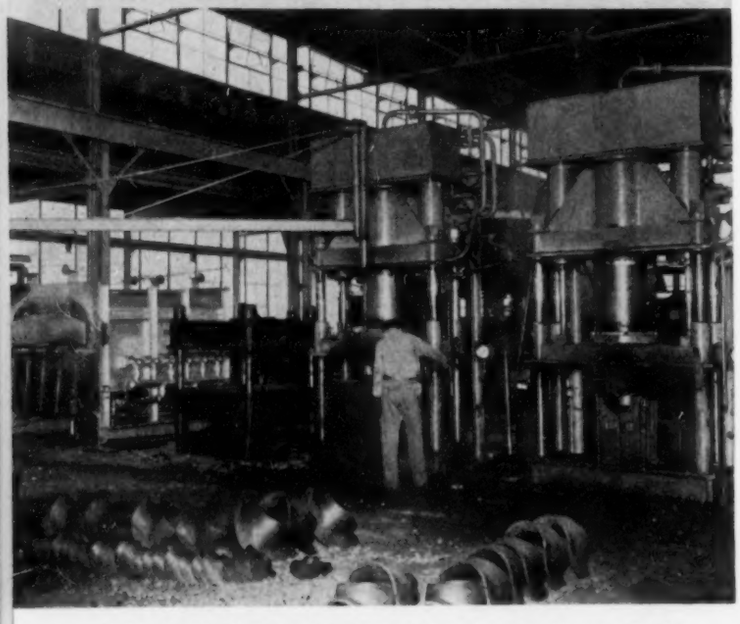


Fig. 14 (Top)—Machine Facing a Special Low-Pressure Flanged Fitting

Fig. 15 (Center)—Pipe Assembly on the Testing Rack

Fig. 16 (Bottom)—Hydraulic Presses. In the Foreground Are Shown Some Reinforcing Saddles

we use a turbine type of cleaner, much the same as that used to clean flues in a boiler and tubes in an oil-refining furnace. The equipment consists of various sizes of turbines together with universal joints and cleaning heads to take from 2-inch diameter up to and including 20-inch diameter pipe. This equipment will pass around a bend with a radius of three times the diameter of the pipe.

Portable grinding machines with extended spindles and some with flexible shafts are used to clean up the welds on the inside of the pipe where they can be reached from either end. In the case of piping assemblies using short radius fittings where it would be impossible to pass the turbine cleaners through, the various parts of the assembly are cleaned as fabricated, before welding together the entire unit, thus leaving only a short section to be cleaned after the unit is completed.

Testing Rack

Figure 15 shows a pipe assembly on the testing rack preparatory to making hydrostatic tests. This rack is used as a means of supporting the pipe and holding it in position during the test. Manifolds and connections are provided to supply air at 100 pounds pressure from the main shop system or air up to 300 pounds pressure from a booster pump. Water pressure can be either the city water pressure or by means of high-pressure pumps carried up to 4000 psi. We have a limited capacity of water to 10,000 psi which is used for research work in testing fittings and other apparatus to destruction for tests. An assortment of heads, blind flanges and closure pieces with the necessary bolts is stored in shelves and on benches. Air-operated wrenches are used which limit the amount of stress that can be put into a given size bolt and also make for quick closing and disassembly. Upon completion of the testing procedure, the water is allowed to drain from the pipe through a grating and carried away from the table to a sump.

Handling

The handling of both large and small pipe assemblies of intricate shape becomes quite a problem and, owing to their shape, must of necessity be handled by overhead apparatus. The entire fabricating shop is covered by electric traveling cranes with capacities of from one to fifteen tons, and are supplemented by the use of electric powered jib cranes. These jib cranes are placed over the welding positioning machines as well as other apparatus in the shop. Whenever possible rope slings are used instead of chains or steel cables as they are less likely to slip and cause injury to workmen and equipment.

Auxiliary Equipment

In addition to the equipment described, we have in our shop large bending tables and suitable gas-fired furnaces which have a capacity of bending up to 30 inches diameter pipe, coiling and bending machines capable of handling up to 6 inches diameter either in regular bends or continuous coils, vanstone and flanging machines capable of handling from 1 to 30 inches diameter pipe and various types of lapped joints in these diameters. The machines are capable of upsetting sufficient metal from the pipe itself to allow full pipe wall thickness at the bottom of the groove which sometimes means that the

thickness of the rough forged lap is three times the wall thickness of the pipe.

Facing machines are provided to machine various type facings and the O.D. and the back of the lap to make a good fit between the upset joint and the companion flange. These facing machines are also used to shape the various types of U groove facing on ends of heavy pipe and fittings preparatory to welding.

With the advent of welding and the design of odd shapes of piping and fittings, some form of pressing machine is a necessity to a well-organized fabricating shop Figure 16 shows two types of hydraulic presses which were designed and fabricated by our shop organization. These machines are of plate and welded construction and some of them have been in use for over eight years without any defects showing up in the design of the various welded parts. Figure 16 shows two types of hydraulic press machines having a capacity of from 50 tons to 250 tons pressure on the ram and with platens or die capacity from 1 foot square to 6 foot square. In the foreground are shown some reinforcing saddles made on these machines.[4] These machines are also used in the manufacture of a line of welding fittings in various types suitable for all pressure and temperature conditions commonly used in piping installations. The sizes range from $^3/_4$-inch pipe size to 30-inch O.D. pipe diameter.

Field Welding[2, 8, 11]

As mentioned before the amount of field welding should be held to a minimum and where field welding is done it should be done under competent supervision and all precaution taken to insure good welds and overcome the handicap due to lack of machines and equipment.

It should be remembered that the welds in a piping system must at all times and under all conditions be equal to the strength of the piping joined by welding. Engineers and designers are eliminating from their calculations the extra allowance in pipe wall thickness formerly used to compensate for threads and flanged connections. The only yardstick used, therefore, should be that determined by the material and the thickness of the piping parts joined by welding. The quality of the finished weld must be 100% of the parent metal.

While the writer has taken some exceptions to certain practices and codes, it was done in the constructive nature and with the thought that the suggestions offered will help to advance the art of welding generally, and especially as applied to piping.

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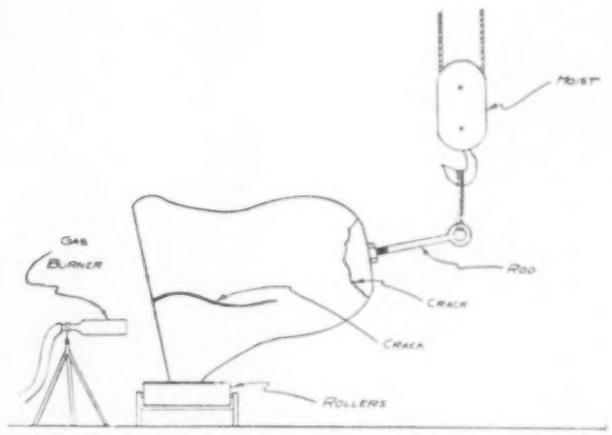
Arc Welding Restores Tone to Old Rio Grande Mission Bell*

By H. P. Rigsby†

THE Catholic church of College Station, Texas, brought me an old 400-pound brass bell which has been damaged in the Rio Grande Valley Mission fire. The problem was to weld two cracks in the bell—one running from the lip up 17 inches and another 10-inch crack around the top.

My first thought was to chip out the cracks with a hammer and chisel, but I soon realized that this would be a long, laborious task since the bell in its heaviest portion was about $2^1/_2$ inches thick. I decided to arrange the bell as shown in the drawing so that it could be easily handled and so that I could preheat the bell with a gas burner to about 500° F. Next I scarfed the cracks with an electric arc welder, using a $^3/_{16}$-inch mild steel mineral coated electrode at about 300 amperes. The scarfing was easily accomplished in about 30 minutes.

After burning out the cracks I cleaned the deposits of slag and burned metal out with a hammer and chisel. I



began welding with $^1/_4$-inch coated electrodes, applying the weld in layers and cleaning thoroughly between each pass—keeping the temperature of the bell to between 500 and 600° all the while.

After the welding was completed I covered the bell in order to eliminate all drafts and cooled it very slowly by gradually cutting down on the heating flame.

The result was a perfect restoration of tone to the old bell. May I add that, in this case, electric arc welding certainly furnished an easy, economical way of handling what would have been, by any other method, a very difficult job.

* Courtesy Hobart Brothers Co.

† Mechanical Engineering Department, Texas A. & M. College.

A Modern Type of Welded Iron Towboat

By J. Murray Watts*

TO SHOW the scantlings and distribution of weights of construction on a small commercial boat, I present a design of an all-welded Diesel towboat. The dimensions are 65 ft. x 17 ft. x 6 ft. 9 in. draft. She is powered by a 240-hp. Fairbanks-Morse Diesel engine drawing a three-blade cast-steel wheel 58 in. x 26 in.—the *H. B. Mortimoore*, owned by American Dredging Co., built by Robins S. B. Co. and designed by the author.

For auxiliaries she has a $2^3/_4$-kw., 110-volt generator driven by a diesel engine located on the starboard side. This also drives through clutches an air compressor and a 3-in. fire and bilge pump. To starboard she carries an auxiliary outfit consisting of a sanitary pump and service pump.

Just forward of the engine room is a fuel tank holding 16 tons of oil.

The water is carried in forepeak tank and afterpeak tank.

Lubricating oil is carried in a 100-gallon cylindrical tank.

The construction details are as follows:

Keel and Stem, 6 in. x 1 in.
Frame, $2^1/_2$ in. x $2^1/_2$ in. x $^5/_{16}$ in. T-bar fitted with flange of angle inside, spaced 20 in., except in bow, 15 in., for ice
Web-frame, 9 in. x $^1/_4$ in. with 3 in. x $^5/_{16}$ in. flat face bar
Shell Plating, $^1/_4$ in. Byers iron
Deck Plating, $^1/_4$ in Byers iron
Rail Plating, $^3/_{16}$ in. steel
House Plating, $^3/_{16}$ in. steel
House Roof, $1^1/_2$-in. pine covered with 10-ounce canvas
Bulwark, 22 in. high
Bulwark Braces, $3^1/_2$ in. x $3^1/_2$ in. x $^5/_8$ in. T-bars, spaced 3 ft. 6 in. except in bow, 5 ft. 0 in.
Floor Frames, 12 in. deep, $^1/_4$ in. plate, with $2^1/_2$ in. limber hole, except in bulkheads
Floor Frames in Engine Room, $^5/_{16}$ in.
Keelson, 3 in. x 3 in. x $^5/_{16}$ in. T-bar except in tanks, where there is a longitudinal bulkhead
Stringer, 3 in. x 3 in. x $^5/_{16}$ in. T-bar
Deck Beams, 4 in. x 3 in. x $^5/_{16}$ in.
Deck Beam Brackets, 11 in. x 11 in. x $^3/_8$ in.
Side Deck Beams and Brackets Combined, 8 in. x 4 in. x $^1/_4$ in.
Fenders, 3 in. X-heavy pipe supported by $^3/_8$ in. x $2^1/_2$ in. flat bars, welded
Cabin Beams, 2 in. x 2 in. x 4.1 lb.
Brace under Bitts, 4 in. x $^1/_4$ in. T-bar 8 ft. long, intercostal
Bulkheads to be of $^1/_4$-in. plate and stiffened with $2^1/_2$ in. x $^3/_{16}$ in. stiffeners, located as shown (Oil Tank $^1/_4$ in. BHD)
The rudder stock is a 3-in. shaft, 10 ft. 9 in. long, weight 258 lb.

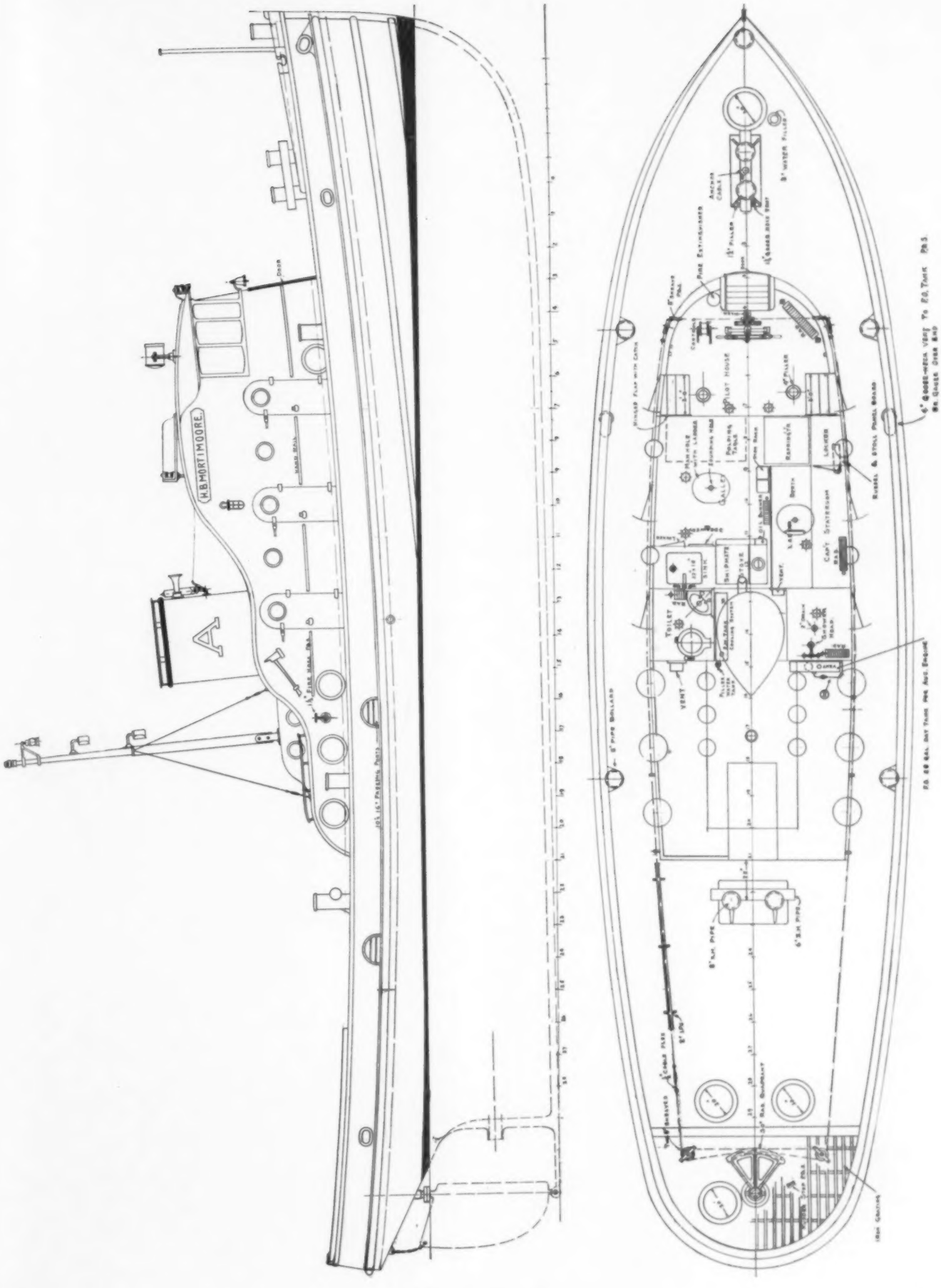
* Consulting Engineer and Naval Architect, Philadelphia, Pa.

65′ Tug H. B. Mortimoore (All Welded)

The rudder port is a $3^1/_2$-in. X-heavy pipe
The rudder blade is streamlined, of 2 plates, $^3/_{16}$ in. thick, welded together at the edges, weight 300 lb.
The quadrant is a stock type, 26 in. radius, mounted on a bearing on deck
The upper part of the stern post is of 6 in. x $1^1/_2$ in. plate, welded to the transom plate above, and to the stern tube below
The lower part of stern post is 6 in. x 2 in. plate welded to stern tube on top, and to 3 in. x 4 in. skag below
The stern tube is an 8-in. X-heavy pipe welded to the two halves of the stern pots. It is 8 ft. 0 in. long and has a rubber cutless bearing at the after end, and a stuffing box at the inboard end. It is $^1/_2$ in. thick, and weighs 347.2 lb.
The shaft will be 4 in. diameter, and the tail shaft, $4^5/_8$ in. diameter
The propeller is 58 in. diameter, suitable for the 240-hp. engine. It shall be a three-bladed "Michigan" cast-steel make

Estimated Displacement, 75 Tons

	Tons		Tons
Keel Stem and Stern Post	0.8		
Frames and Web Frames	4.5		
Floor Frames and Engine Beds	2.7		
Deck Beams and Brackets	1.8		
Stiffeners	0.2	Framing	12.74
Bilge Stringer	0.48		
Waist Frame Bulb L and Fender	2.00		
Engine Room Flooring and Grating	0.12		
Stern Tube	0.15		
Shell Plating	9.4		
Bulwark Plating	0.7		
Deck Plating	3.0		
Bulkheads Plating	1.5	Plating	16.8
House Plating	1.6		
Welding Rod	0.6		


H.B.MORTIMOORE.
PILOT HOUSE
TOILET
VENT

	Rudder	0.25	Fuel and Piping	16.00
(58 in. x 26 in.)	Propeller	0.26	Water and Piping	2.75
	Shaft	0.50	Hull Machinery and Tanks Total	67.55
	Main Engine	16.	Furniture and Equipment	7.00
	Aux. Machinery	2.5	With Equipment Total	74.55
	Exhaust Pipes	0.25		
	Mufflers	0.5		

Arc Welding of Chrome-Molybdenum Sheet and Tube in the Aircraft Industry*

By F. R. Kostoch†

Introduction

WITH the unprecedented activity and the increased production demanded of the aircraft industry, every effort must be made to utilize those methods which are both dependable from the engineering point of view and time saving as well. Older time-tested methods are being discarded and replaced by newer, faster ones. Notable in this regard is the progress of arc welding.

But, as with many another change, problems arose rapidly. Sufficient electric welders skilled in the technique required for aircraft production were not available. Research on machines and materials utilized was lacking. As a result, gas welders were converted to electric welding without sufficient preliminary training and unsuitable equipment was used. Naturally in these instances both the quality of the work and the efficiency of the department suffered.

In spite of the difficulties first encountered, the use of electric arc welding is almost mandatory. Time is of the essence and when it is realized that time savings of from 75% on small pieces to not less than 45% on complete fuselage assemblies may be effected, this is readily apparent. Savings in cost of both labor and material may be increased correspondingly and lastly, all conditions being equal, it is much easier and less time-consuming to develop electric arc welders than gas welders.

Equipment

The first prerequisite for welding is, of course, a suitable generator. Many of those available were not designed for the factors encountered in aircraft welding. Obviously, the welding of a cluster of thin tubes is very different from pipe-line construction or ship building. A much lower amperage is generally used in aircraft fabrication (from 45 to 65 amperes in contrast to 140 or more). As a result many generators produced arcs which at the low amperage failed to produce a voltage sufficient to give good striking characteristics, arc stability and arc control. These factors are important in the "laying down" of a good weld. Inability to strike an arc will cause "freezing-on" of the electrode which invariably results in the pitting of the tube and this is cause for rejection of the assembly by the inspector.

Design to eliminate noise, while not of primary importance, will be of value because of the bettered working conditions which usually increase efficiency of production in the department.

The action of the electric arc is roughly comparable to the electric- or open-hearth furnace for steel production. As in pouring ingots, at the completion of the operation a molten puddle remains which solidifies from the edges toward the center. Thus an opportunity for inclusions of gases and slags is present and craters in the weld end are formed because of the thin-walled tubing used and the relatively short welds, the formation of craters in weld endings and tack welds is definitely detrimental.

Various methods have been devised to remedy or alleviate this undesirable condition: lengthening the arc at the end of the weld, "wiping" the weld by oscillation of the electrode, overlapping the weld, and the use of a number of stringer beads as in ship building. Most of the foregoing will give a smooth, dense-appearing surface but will show gas pockets upon cutting and etching.

As may be seen in Fig. 1, the surface of the weld is smooth and even in contour. However, large craters

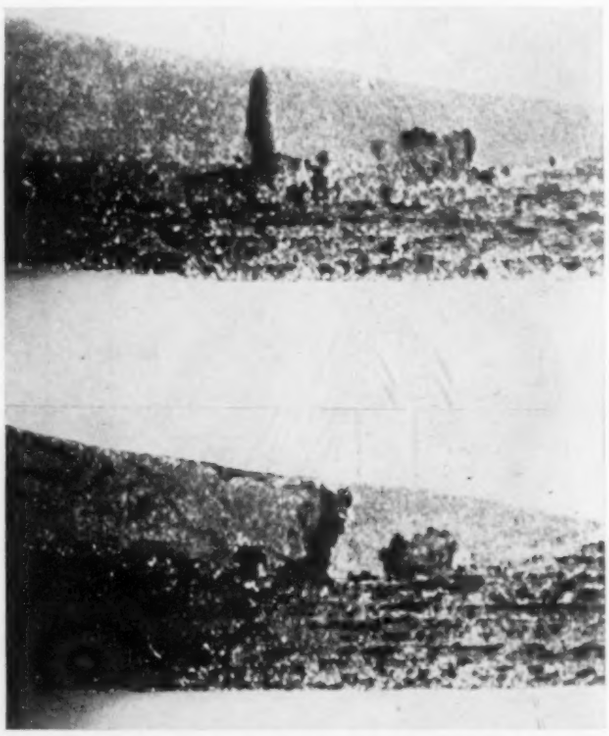


Fig. 1—Weld Endings Made by Lengthening the Arc

* Presented at Western Metals Congress, AMERICAN WELDING SOCIETY, Biltmore Hotel, Los Angeles, Calif., May 19–22, 1941.

† North American Aviation, Inc., Inglewood, Calif.

are visible which begin but a few thousandths below the surface and extend into the parent metal. As these are representative of a great number of similar specimens it may be seen that this method merely hides the crater and does not eliminate it.

The use of the "crater eliminator" appears to have solved this problem. The eliminator consists of a motor-driven rheostat in the generator excitation circuit and is set into action by the operator by means of a small push-button switch on the electrode holder when approximately $^1/_2$ in. from the end of the weld. The gradual diminution of current results in a slow quenching of the arc until at the finish no puddle remains in which gas pockets may be formed. The penetration is somewhat lessened, but this is found in weld endings irrespective of whether or not the eliminator is used.

Figure 2 illustrates the differences in weld endings made with and without the eliminator. The value of the use of the machine is readily apparent upon comparing the large craters formed in *A*, *B* and *C* with the dense, fine-grained deposit in *D* and *E*. These photomacrographs also illustrate that there is no appreciable difference in penetration when the eliminator is used.

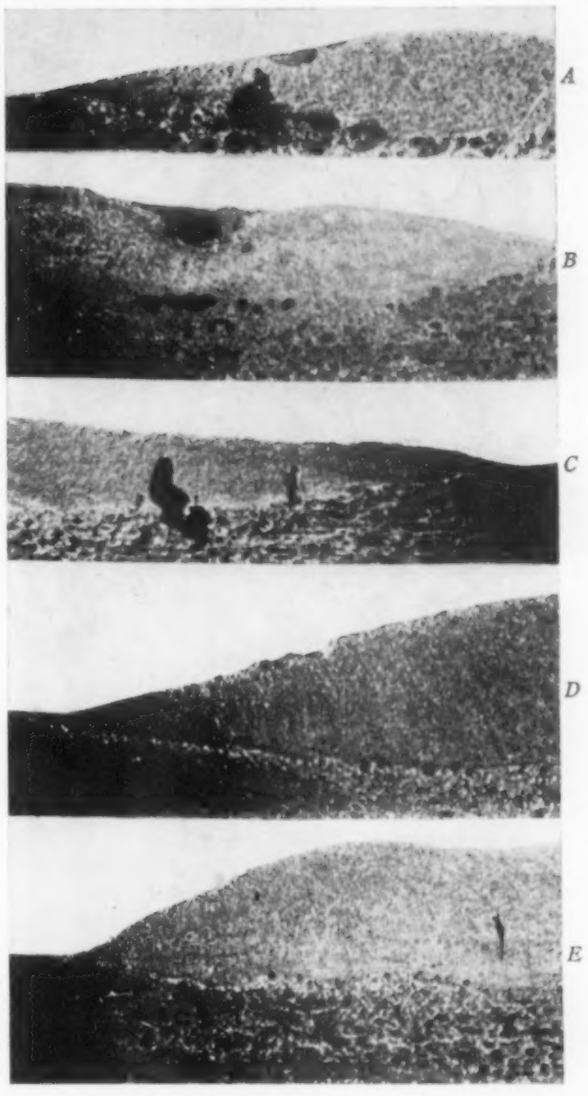


Fig. 2—Cross Section of X4130 Steel Arc Welded
Macrophotographs *A*, *B* and *C*: Without Crater Eliminator
Macrophotographs *D* and *E*: With Crater Eliminator

Materials

Chromium-molybdenum steel, SAE X4130, has replaced almost entirely the use of low carbon steels for fuselage construction.

SAE X4130 derives its great value from the fact that the alloy has a high strength–weight ratio, is easily weldable, does not require heat treatment subsequent to welding and is air hardening.

This air-hardening feature is most important since this results in the weld closely approximating the strength of the parent metal. The heat developed in the operation will cause a decrease in the tensile strength of the heat-affected zone but this decrease will not exceed 10% of the original.

The majority of the manufacturers use the electric furnace method to make the chrome-molybdenum steel of so-called "aircraft quality," but due to the great increase in demand it may be necessary to return to the open-hearth method.

Because of the need for great strengths in the highly stressed parts and the premium placed on light weight, aircraft tubing must be a clean homogeneous product. Too much emphasis cannot be placed upon uniformity in the steel. Sulphur and phosphorus must be kept to a minimum to insure good weldability and freedom from the tendency of the weld to crack. "Fine-grain" is highly desirable, for "coarse-grained" steel is much more difficult to weld.

Tubing is supplied according to U. S. Army and U. S. Navy specifications with the following analysis in percentages:

Carbon	0.27 –0.33
Manganese	0.40 –0.60
Chromium	0.80 –1.10
Molybdenum	0.15 –0.25
Phosphorus	0.040 (Max.)
Sulphur	0.045 (Max.)

Grain size is limited to size 5 or finer and the majority of the tubing supplied is in normalized condition. In certain specific instances it may be supplied in the heat-treated state (oil quenched and drawn).

For thin sheet and tube a mild steel electrode is recommended and for thicknesses of $^3/_{16}$ in. or greater a special heat-treatable alloy steel rod is used. In each case the electrode is heavily shielded.

The careful selection of proper electrode shielding is important. The coating shields the arc and forms an inverted crucible at the end of the electrode insuring even deposition of weld metal. It protects the weld deposit by the formation of a slag excluding the oxygen and nitrogen of the air and may contain oxides and silicates which upon reduction deposit the metallic constituents in the weld thus approximating the analysis of the parent material. The uniformity of the electrode coating is also important. Irregularity makes control of the arc difficult.

Design and Procedure

Proper joint design is very important in regard to aircraft welding. Lack of welding knowledge on the part of design engineers often results in "overdesigning" a joint. As a result, labor and material costs increase and unnecessary weight is added. The possibility of making a joint too rigid must also be taken into consideration. Excessive use of gussets or lengthy welds may cause failure of the tubing due to the vibrational stresses in the

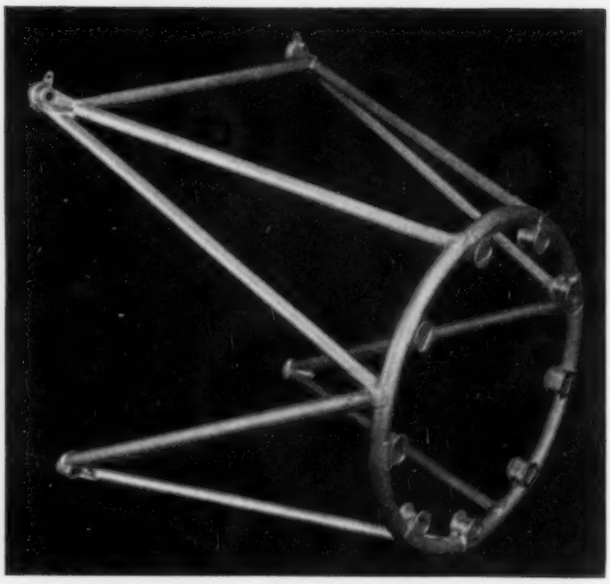


Fig. 3—Arc Welded Motor Mount

structure, which are not released. This is particularly important in such assemblies as the motor mount shown in Fig. 3. These are subjected to much vibration and if the joints permit no freedom of action the weld is very likely to crack. The type of gusset used on this mount has been very satisfactory even though it is one of the oldest types. Strength and ability to withstand vibrational stress are both achieved.

Figure 4, a fuselage front assembly, illustrates this "wrap-on" type of gusset as well as the usual plate type. Note, however, the small size of the plate. Analysis of the structure under all types of load, including "turnovers" and other abnormal conditions, showed that this was sufficient to give the required strength.

A maximum tensile strength of 80,000 psi is the usual designed for in plain, butt-welded joints, plain telescope or lap-welded joints, tapered welds with angles greater than 30° to the center line or fish mouth welds with an included angle greater than 60°.

Tapered welds with angles less than 30° to the center line or fish mouth welds with an included angle of less than 60°, are designed for 90,000 psi.

As has been mentioned heat treatment subsequent to welding is not necessary. The air-hardened weld is strong and if carefully done on good base metal will require no strain relieving. In this respect the lower the carbon content of the base metal the better will be the weld.

This statement is not as contradictory as it may seem. The air-hardening feature is important and were this the only consideration the upper limit specified would be quite satisfactory. However, we must strike a happy medium between this and weldability. If the carbon content can be held closer to the lower allowable limit the welding will be easier and there will be much less chance of the weld cracking due to stresses set up by the hardening.

The value of this steel will readily be seen when the cost of equipment needed and time spent on heat treating an entire fuselage assembly is calculated. In a few instances, such as on welded motor mount rings, strain relieving may be desirable. This may be done either by heating to 800 or 900° F. with a torch or actual normaliz-

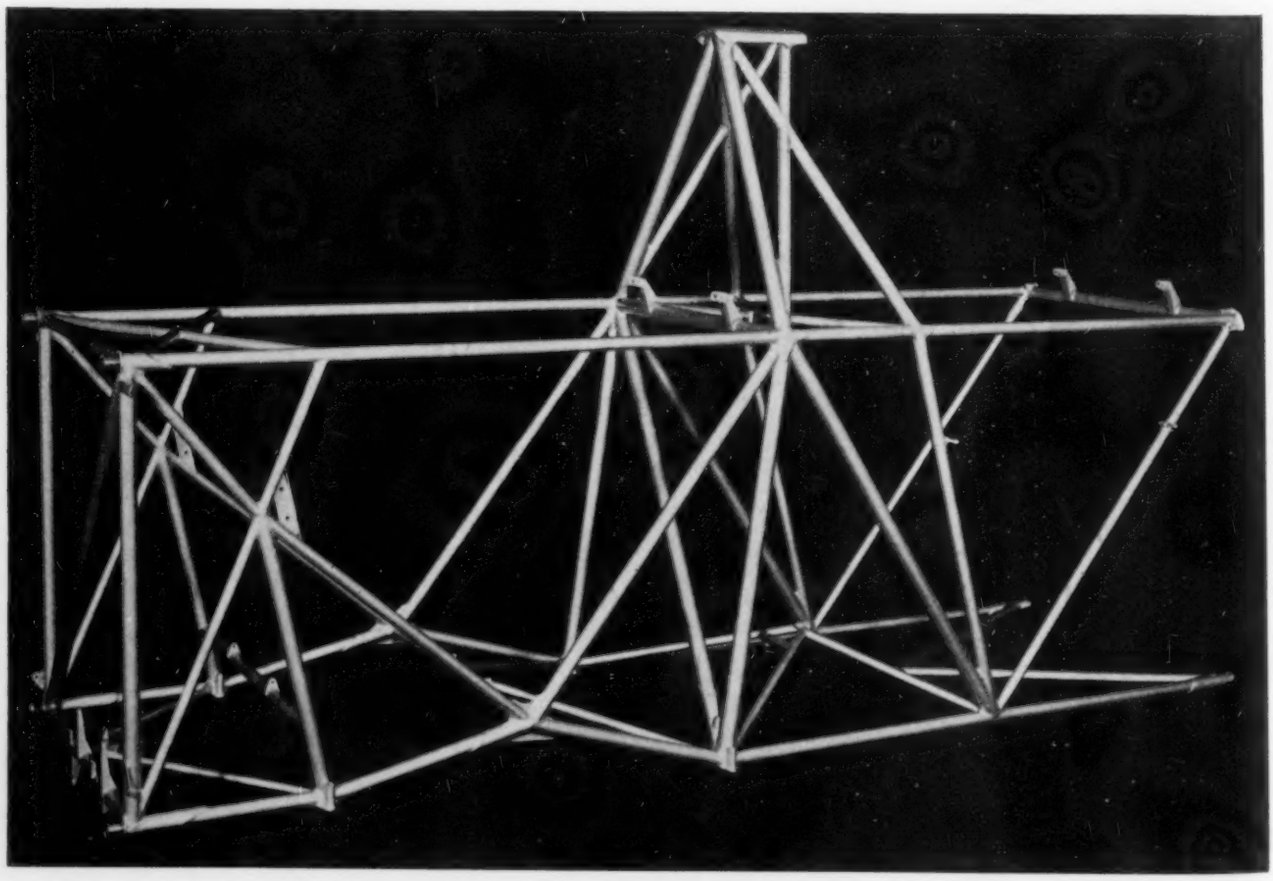


Fig. 4—A Fuselage Front Assembly

Heat Treatment, ° F.	Tensile Strength, Psi	Yield Point, Psi	Elongation, 2 In.—%
None	95,000	60,000	12.0
Normalized 1500–1600; still air quench	100,000	80,000	15.0
Heat treat 1500 oil quench, drawn 600	200,000	150,000	....

(From "Molybdenum in Steel," Climax Molybdenum Company)

ing at 1600° F. This is usually a precautionary measure. An example of heat treatment of welding tubing may be of interest.

Some difficulties have arisen in the welding of tubing to forgings. Several reasons for this have been advanced. In the first place, the carbon content of the forging is generally on the high side of the allowable, and as was explained earlier in this paper this will increase any tendency to crack which may be present. Secondly, the steel manufacturers usually keep the sulphur and phosphorus on the high side to increase machinability. As a result, the weld will be porous due to gas formations. The surface may be reasonably good, but the interior will be filled with innumerable pinholes. Thirdly, if the chromium and molybdenum are low and the carbon high the forging will have a lower melting point than does the tube and thus increase the difficulty encountered in welding. Lastly, forging and possibly machining will undoubtedly set up unknown amounts of strain in the part. Upon welding the localized heat may result in increasing the strain at some other point and unless this is relieved the welded joint will be subjected to strains which may result in fracture.

With regard to the relieving of the strains, it has been found the use of a gas torch to "strain relieve" the forgings in the neighborhood of 700–900° F. is not satisfactory. Normalizing (1600° F. and still air quenching) has been found to remedy the difficulty very well.

One other point might be mentioned. If the forging is large enough it may require a larger bead to be laid down. In this case a larger electrode will necessitate a welding heat of perhaps 80 amperes in contrast to the usual limit of 50 amperes. Care must then be taken lest the tubing be burned through in the process.

The fact must not be lost sight of that welding is a manual practice and thus much dependent upon the idiosyncracies of the individual welder. Because of this there are certain phases of shop practice to be taken into consideration. For production line work much can and should be specified as, for example, the type of equipment and the various kinds of electrodes to be used. But conditions may vary greatly in some respects. Atmospheric conditions, current supply, change of machine and position all exert an influencing effect on welding.. Thus it is almost impossible to specify the polarity to be used, voltage and current settings and speed of weldings. Normally straight polarity, i.e., with the electrode negative and low current with the highest voltage which still permits accurate control of the arc, will produce the best results.

Little or no processing of the work prior to welding is necessary. Some assemblies are preheated but the practice is by no means general. The edges of the joints do not require special cleaning other than ordinary precautions to prevent dirty surfaces. Cleaning of the weld may be done by wire brushing or sand blasting. The latter is preferable from the standpoint of appearance.

The welds are inspected in several ways. Visual inspection is usually used in the production. Complete assemblies may be pressure tested with air and soap solution, in which case cracks will be disclosed by the air bubbles formed, or they may be tested by magnetic inspection. The latter is particularly valuable in that it discloses subsurface flaws not readily detectable except through destruction of the weld.

Physiological and Psychological Effects

By providing adequate protection from the arc and by using non-toxic electrode coatings, little or no danger exists in arc welding. Proper clothing and eye shields will eliminate any danger of eye strains or burns. The use of electrode coatings containing compounds which are toxic are not permitted or are definitely prohibited. Only adequate ventilation is needed to remove the fumes which are produced by the burning electrode coating.

On the whole the welder will find electric arc welding easier than gas welding because of several factors.

1. The method requires less muscular coordination and less mental concentration, on the mechanical function, because there is no need to use the weaker left or right hand as the case may be.
2. There are fewer variables to control in arc welding, i.e., less expansion and lessened zone of heating, puddle characteristics are more easily controllable and the arc is more easily controlled than is the flame of the torch.
3. Stronger welds are produced since the filler material absorbs the characteristics of the parent metal which is not the case in gas welding.

Future Development

When all factors are considered it will be seen that electric arc welding will be the predominant type of fusion welding for aircraft structures. Research will undoubtedly lead to better material, equipment and methods.

The greatest step in the future will be the formulation of a code of standard procedure for aircraft structure welding. Standardization without question will be difficult because much depends upon the skill and eccentricities of the operator. But, the use of certain specified equipment, e.g., crater eliminators, etc., may become obligatory in order to meet the rigid standards that must eventually be imposed if the aircraft industry is to increase production and maintain the dependability of its products in the face of increased output.

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Welding Metallurgy

VOLUME II

By O. H. HENRY and G. E. CLAUSSEN

A series of lectures prepared for presentation in a fundamental course of metallurgy and metallography at Polytechnic Institute of Brooklyn under the joint auspices of the Institute and the New York Section of the AMERICAN WELDING SOCIETY. To be published serially in The Welding Journal. The lectures are reproduced in attractive booklet form, copiously illustrated—357 pages—with imitation black leather covers. Volume 1 consists of the first series of 10 lectures given by the New York Section in cooperation with the Polytechnic Institute of Brooklyn last year. Volume 2 includes the series of lectures given this year. The price of the book containing both volumes is $1.50 per copy. Special prices can be arranged for quantity lots of 50 or more.

Part VII—Stainless Steels

Stainless steels contain large percentages of chromium, and resist corrosion by many of the reagents that rapidly corrode plain-carbon and low-alloy steels. The hundred or more different compositions of stainless steels fall into three main groups in the order of importance for welding.

1. Austenitic or chromium-nickel group, the most important members of which are the eighteen–eights (18–8) containing 18% Cr and 8% Ni.
2. Non-hardenable or ferritic straight chromium irons containing over 15% Cr or more.
3. Martensitic or hardenable, straight chromium steels containing 16% Cr or less.

The high corrosion resistance of the straight chromium steels under oxidizing conditions, such as nitric acid, is conferred by the chromium content. The additional nickel content of the austenitic steels confers resistance to reducing agents such as hydrochloric acid, against which nickel, but not chromium, is resistant. The resistance of these alloys to corrosion was said in the introduction to Part VI, Vol. II to arise from toughness on an atomic scale. That is, the atoms at the surface of the metal in contact with the corroding agent are able to withstand the forces tending to pull them into it. The surface of stainless steel should be clean, smooth and unstrained. Otherwise, the corrosion resistance is lowered, for the corroding agent, Fig. 46, is able to act on exposed atoms from nearly all sides, and can become increasingly concentrated in the quiet backwaters represented by cavities or scratches on the surface. For these reasons stainless steel parts should be cleaned thoroughly after welding, the welds should be smoothed, and shrinkage stresses should be relieved whenever service conditions are severe.

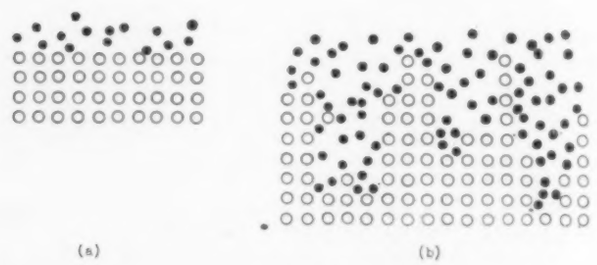

Fig. 46

(a) Smooth surface
(b) Rough surface

The open circles are atoms of the steel. The small black circles are ions of the corroding liquid. They are about to attack the metal. The ions more nearly surround many of the surface atoms of the rough surface than of the smooth surface. The rough surface is the more rapidly attacked

AUSTENITIC STAINLESS STEELS

The major varieties of austenitic chromium-nickel stainless steels are listed in Table 1. Grades 1 and 2 differ in carbon content from Grades 3 and 4. Grades 5 and 6 are known as stabilized 18–8, owing to their titanium or columbium content. Grade 10 is better known as 25–20, while Grade 11 is molybdenum 18–8. The increase in chromium and nickel content in 25–20 increases the resistance to corrosion to a number of reagents.

Unless the minimum chromium and nickel contents listed in Table 1 are present, the alloy is likely to have inadequate corrosion resistance. Besides the surface condition and alloy content, the structure of the alloys governs their corrosion resistance. All three factors, particularly the last, are involved in welding.

The outstanding characteristic of the chromium-nickel stainless steels is their austenitic structure, which distinguishes them from plain-carbon steels. The structure of plain-carbon steels is shown by the iron-carbon diagram, Fig. 47 (*a*), which was explained in Part V of Vol. I. The diagram shows that under equilibrium conditions plain-carbon steels above the critical range consist of austenite, which is a solid solution of carbon in gamma iron. The carbon atoms fit in the spaces among the iron atoms. On cooling slowly below the critical range the atoms of face centered cubic iron (austenite) change their positions with respect to each other to form body centered cubic crystals known as alpha iron

or ferrite. At the same time most of the carbon atoms collect iron atoms around them to form crystals of Fe_3C,

Table 1—Some Types of Corrosion-Resisting Chromium Nickel Steels Listed in A. S. T. M. Standard A 167-39

Grade	Type No.	C	Mn Max.	S Max.	P Max.	Si Max.	Cr Min.	Ni Min.
1	301	0.08–0.20	1.50	0.030	0.035	0.75	16.00	7.00
2	302	0.20	1.50	0.030	0.035	0.75	18.00	8.00
3	304	0.08 max.	1.50	0.030	0.035	0.75	18.00	8.00
4	308	0.08 max.	1.50	0.030	0.035	0.75	19.00	10.00
5	321	0.10 max.	1.50	0.030	0.035	0.75	18.00	8.00
6	347	0.10 max.	1.50	0.030	0.035	0.75	18.00	8.00
10	310	0.25 max.	2.00	0.030	0.035	2.00	24.00	19.00
11	316	0.08 max.	2.00	0.030	0.035	0.75	16.00	10.00

Grade 5 contains titanium in addition: Ti equals at least 4 times carbon content. Grade 6 contains columbium in addition: Cb equals at least 10 times carbon content. The steels corresponding to Grades 5 and 6 are specified by A. S. M. E. Boiler Code Case 836 to contain 0.07% max. C, 0.4–2.50% Mn and the titanium content must be 6 times carbon content. Grade 11 contains 2.00–3.00% Mo in addition. All grades are specified to have tensile strength equal to at least 75,000 lb./in.^{2} The minimum Ti and Cb content of stabilized molybdenum 18–8 need be only 60% of that without molybdenum, due to the stabilizing action of Mo (Boiler Code Case No. 861). According to Boiler Code Case No. 834, weld metal for stabilized 18–8 should have 0.07% C, max., 0.40–1.50% Mn, 17% Cr, min., 9.5% Ni min. and Cb% at least 9 times carbon content, not over 1.0%, or Ti at least 5 times carbon content, not over 0.6%.

called iron carbide or cementite. The remainder of the carbon is in solid solution in the ferrite. On rapid cooling the iron atoms in the austenite do not have time to make the change to body centered cubic arrangement; instead they change to martensite. It happens that the arrangement of atoms in martensite is an arrangement in the complete process of changing the face-centered cubic crystal to body-centered form.

Turning to Fig. 47 (*b*), we observe a resemblance between the iron-carbon diagram and the similar "18–8"-carbon diagram. Instead of adding carbon to iron, we add carbon in increasing amounts to an alloy of iron with 18% Cr, 8% Ni. Similar points in the two diagrams of Fig. 47 are given the same letter. There are two main differences between (*a*) and (*b*). First, where, in (*a*) the changes at points *A*, *N* and *G* and along lines *HB* and *PS* occur at a single temperature, in (*b*) these changes or reactions go to completion over a range of temperatures, in accordance with the fundamental rule upon which the iron-carbon diagram itself is based. For when 0.4% C is added to iron, the alpha-gamma change occurs over a range of temperatures instead of at a single temperature, as in iron free from carbon and alloying elements. The second difference is more important. It is far more difficult, that is, it requires far longer times, to attain equilibrium in 18–8 than in plain-carbon steels. For this reason it is extraordinarily difficult to be certain that we know the true equilibrium structure of 18–8, and indeed all the lines in Fig. 47 (*b*) are nothing more than judicious guesses.

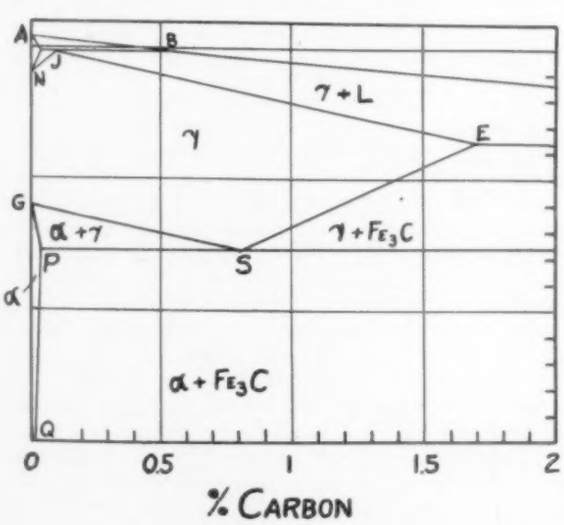

Fig. 47 (*a*)—Iron-Carbon Diagram

Point or Lines	Significance in Fig. 47 (*a*)
Point *A*	Melting point of iron
Line *HJB*	Liquid *B* and alpha (delta) H* react to form gamma *J*
Point *E*	Maximum solubility of carbon in gamma
Point *G*	Gamma changes to alpha
Line *GS*	Ferrite (alpha) commences to separate from austenite (gamma) on cooling
Line *GP*	Gamma starts to separate from alpha on heating
Line *PS*	Gamma changes to a mixture (called pearlite) of ferrite and cementite
Line *PQ*	Cementite (iron carbide = Fe_3C) commences to separate from alpha on cooling

*H is left end of line BJ

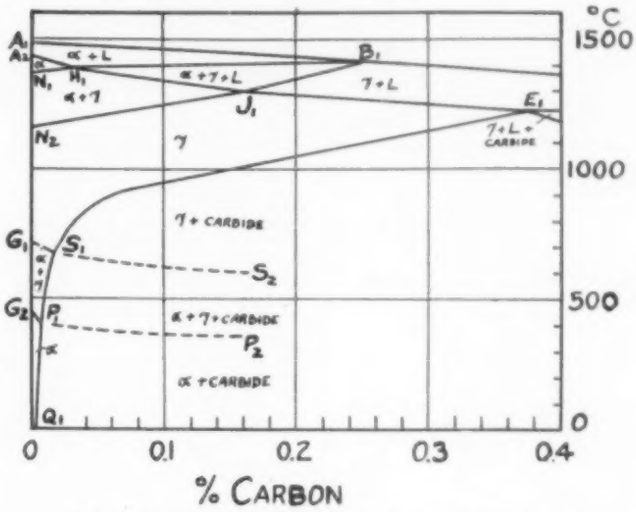

Fig. 47 (*b*)—18–8 Carbon Diagram. (Kinzel and Franks)

Point or Lines	Significance in Fig. 47 (*b*)
A_1 to A_2	Melting range of 18–8 containing 0.00% carbon
Triangle $H_1J_1B_1$	Liquid B_1 reacts with alpha H_1 to form gamma J_1
Point E_1	Maximum solubility of carbon in austenite containing 18% Cr and 8% Ni
Points G_1 and G_2	Range of temperatures in which gamma changes to alpha in 18–8 containing 0.00% carbon
Line G_1S_1	Counterpart of line *GS* in (*a*)
Line G_2P_1	Counterpart of line *GP* in (*a*)
Area $S_1S_2P_1P_2$	Gamma changes to a mixture of alpha and carbide $(Cr, Fe, Ni)_4C$
Line P_1Q_1	Carbide commences to separate from austenite on cooling

Note: In Fig. 47 (*b*) it is not possible to state the composition of the phases in any of the 2-phase or 3-phase areas, such as $H_1J_1B_1$. The Horizontal Law does not apply to (*b*), although it applies to (*a*). The 18–8 diagram is hypothetical except for lines G_1S_1 and G_2E_1 whose locations are known with considerable accuracy. The carbide in diagram (*b*) is believed to be Cr_4C (chromium carbide) with some iron and nickel in solid solution and is called for short $(Cr, Fe, Ni)_4C$.

Consider an 18–8 containing 0.07% C in Fig. 47 (*b*). Above 1475° C. the alloy is molten; the atoms of Fe, Cr, Ni and C are mixed at random. At 1475° C. crystals of alpha form. Often these crystals are called "delta" to distinguish them from alpha crystals which may form below 700° C.; there is no other difference between alpha and delta crystals. At 1400° C. the alpha commences to change to gamma as freezing progresses. The diagram cannot be used to tell us the composition or amount of alpha and gamma that has formed at any temperature. In Fig. 47 (*b*), therefore, we can use neither the Lever Law nor the Horizontal Law. As the temperature drops further, the gamma continues to form and the alpha to disappear, until at about 1350° C. the last liquid disappears. The solid 18–8 consists of alpha and gamma crystals.

During further cooling the alpha should continue to disappear, changing to gamma until at about 1225° C. the last alpha crystals should change to gamma. Yet the structure of 18–8 weld metal as-deposited reveals more or less delta (alpha), Fig. 48, although traces of delta never are found in plain-carbon steel weld metal. The delta persists because equilibrium in 18–8 requires long time and slow cooling, and reaction rates are very slow, as we stated above. The traces of delta play an important part in the corrosion resistance of 18–8 weld metal, for carbide, instead of precipitating elsewhere, precipitates in the unconnected patches of delta, where the carbide is relatively harmless. Long heating at 1100° C. is required to convert the last traces of delta to gamma.

INTERGRANULAR PRECIPITATION

No further change occurs during fast cooling of the austenite from 1100° C. The austenite persists at room temperature unless it is cold worked or reheated. Should the austenite be cooled slowly from 1100° C., crystals of carbide commence to form at 900° C. The carbide is primarily Cr_4C, chromium carbide. It continues to separate during cooling in the same way that carbide separates from ferrite in plain carbon steels along line PQ below 720° C., Fig. 47 (*a*). In the same way that austenite in plain-carbon steels transforms first at the grain boundaries, so the carbide separates from the 18–8 austenite along the grain boundaries, Fig. 49. In separating, carbon and chromium atoms are drawn from the surrounding austenite and combine at the grain boundary. Around each carbide particle is a region nearly devoid of chromium. Having lost its chromium, the depleted area has lost the greater part of its corrosion resistance. A reagent that is able to dissolve the depleted area then is able to make its way along the grain boundaries of the austenite, leading to well known intergranular corrosion (see Fig. 73 of Vol. I).

What are the remedies for intergranular precipitation of carbide? They are:

1. Reduce the carbon content. Reduction in carbon content retards the precipitation of carbide; slower cooling rates are permissible without carbide precipitation in low-carbon 18–8 (0.08% C, max.) than in the higher carbon grades (0.08–0.20% C). Reduction in carbon content also reduces the amount of carbide that is precipitated. To completely avoid carbide precipitation, which occurs in the range of temperatures between about 300° C. and the carbon solubility curve, Q_1E_1, would require a carbon content below 0.01%, which involves exorbitant expense. Although reduction in carbon content is of advantage in reducing the severity of intergranular precipitation, it cannot prevent the precipitation.

Fig. 48—Microstructure of 18–8 Weld Metal Showing Islands of Delta (Alpha) Distributed in Dendritic Pattern Through the Austenite (Gamma)

The microstructure varies with welding conditions and with type of filler metal

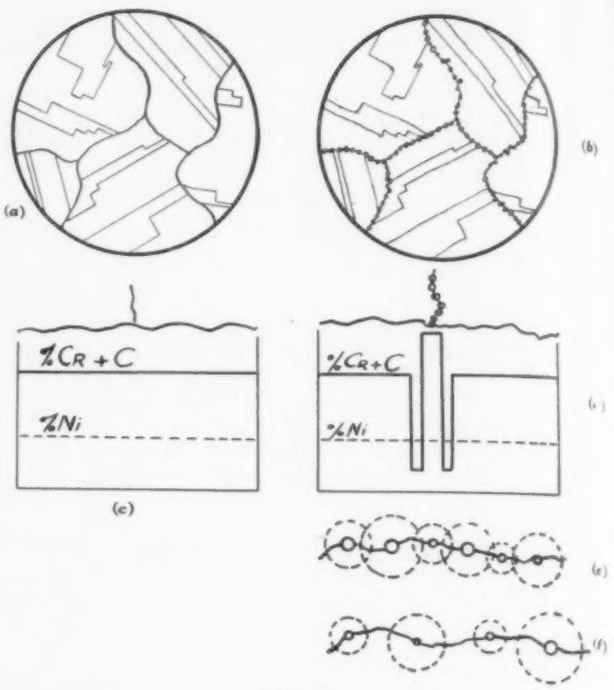

Fig. 49

(*a*) Unstabilized 18–8 showing austenite without carbides
(*b*) Unstabilized 18–8 showing carbide particles in the grain boundaries
(*c*) Diagram showing that chromium and carbon are uniformly distributed in the vicinity of a grain boundary before intergranular precipitation has occurred
(*d*) Diagram showing depletion of austenite in chromium and carbon near a grain boundary on which intergranular precipitation has occurred
(*e*) Interlocking or overlapping depleted areas. The carbides have precipitated along a grain boundary in the heat-affected zone. The dotted circle represents the outer limit of each depleted area
(*f*) The depleted zones do not overlap. The carbides and the depleted areas have been drawn of different sizes because all the carbides are not of the same size nor does the plane of examination cut the centers of all the depleted areas

2. Stabilize the carbide by adding a carbide stabilizing element. The two stabilizers in common use are columbium and titanium, Table 2. They combine with carbon preferentially to chromium, and are called stabilizers because they prevent the 18–8 from changing from a corrosion-resistant state to a corrodible state. Consequently, upon exposure of titanium or columbium stabilized 18–8 to carbide precipitation temperatures, no chromium carbide is formed, provided that the stabilizing element is present in sufficient amounts to combine with all the carbon. During welding unstabilized 18–8 the zone near the weld that reaches 300 to 600° or 900° C. is most susceptible to carbide precipitation. Zones close to the weld and the weld itself cool rapidly through the precipitation range. The zones that have been heated only to 300–900° C. remain longest in that range. Consequently, these are the zones, some distance from the weld, Fig. 73 of Vol. I, in which intergranular corrosion is observed. The weld metal, too, must contain titanium or columbium to remain resistant to attack after another weld has been made close to it, Fig. 50. Since titanium is difficult to introduce into weld metal, owing to rapid oxidation, columbium is the stabilizing element ordinarily used to stabilize weld metal. Titanium is not oxidized from any part of the base metal during welding.

3. Add an alloying element to form ferrite. The carbide precipitates in the scattered ferrite areas instead of in the grain boundaries of the austenite. As a result there is no intergranular precipitation and no intergranular corrosion. Silicon and molybdenum or additional chromium may be added to 18–8 for this purpose, but the effect of ferrite is less pronounced than the effect of carbide stabilizers. Consequently, practically no

commercial use is made of ferrite-forming elements to prevent intergranular corrosion. Silicon may be added to filler rods to combat oxidation of chromium, and molybdenum may be added to base metal to prevent pitting corrosion. Indeed, when molybdenum is added for this purpose the nickel content is increased to prevent the appearance of ferrite.

4. Cold work. If we increase the area upon which carbides can precipitate, we reduce the amount of carbide per unit area. Fine-grained steels require longer time to become susceptible to intergranular corrosion than coarse-grained steels in which the grain boundary area is correspondingly smaller. Cold working creates slip planes which act like grain boundaries to promote carbide precipitation. For welding purposes 18–8 stabilized by cold work generally is not suitable. Around each weld there is a recrystallized zone. Where a second weld crosses the first, Fig. 50, intergranular precipitation is bound to occur in the recrystallized zone, which is devoid of slip planes. When a weld is made in cold worked 18–8 there is a soft zone close to the weld as in any welded, cold worked metal. The recrystallization temperature range of cold worked 18–8 is high: 1000° C. or so, and, although the grain size increases close to the weld, there are no serious consequences, in contrast with 18% Cr iron.

5. Immunizing heat treatment. If unstabilized, cold worked, 18–8 is heated for a time in the upper ranges of precipitation temperatures, for example, 700 to 900° C. (the precipitated carbides are coarser at 700 to 900° C. than at 300–500° C.), the chromium diffuses into the depleted areas and the carbides coagulate. In this way there remains no continuous path for corrosion. Subsequent heating to 300–900° C. causes practically no change in the carbides; practically the entire carbon content remains precipitated at all times. Immunizing is not suitable for 18–8 that is to be welded, for the reason that the carbides re-dissolve in the heat-affected zone of a weld, and precipitate in the grain boundaries when a second weld is made near it, Fig. 50.

HEAT TREATMENT

Immunizing heat treatment may be satisfactory for a welded part after welding is completed and before the part is placed in service, but the presence of carbides, even though not coupled with stress* or depleted areas lowers the general corrosion resistance compared with a part that has been quenched from a temperature at which all carbides are in solution, for example, 1100° C. The immunizing treatment has the advantage over the 1100° C. quench that the part may be slowly cooled from the immunizing treatment, which is often a great convenience, for a large complicated pressure vessel is difficult to quench uniformly, and impossible to quench without creating internal stresses due to quenching. Furthermore, the immunized part is not subject to intergranular corrosion if heated to the precipitation range in service.

Heat treatment is necessary for important and thick welded parts made of 18–8. The Boiler Code Symbol stamp cannot be applied to any welded stainless steel vessel over $^3/_8$ inch thick intended for service in a medium likely to cause corrosion unless the vessel has been stress-relief heat treated, even though stabilized 18–8 be used (Case 861). Shrinkage stresses due to welding must be relieved to prevent stress corrosion cracking, which is of two types: intergranular and transgranular. The intergranular type occurs if a high steady tensile stress, such as shrinkage stress, acts on 18–8 while it is immersed in some types of aqueous chloride and other solutions. In some way the combined action of the stress and of the molecules or ions of the corroding agent cause the grain boundaries to open, hence intergranular cracks without noticeable solution (corrosion) of metal. The effect is similar to the season cracking of brass, which also occurs in the presence of internal stress and specific corroding

* Many authorities believe that the stress created by the earthquake-type of movement resulting from the precipitation of a carbide particle among the crystal planes of the austenite accounts for the reduction of corrosion resistance at the grain boundaries. The stresses are called "transformation stresses."

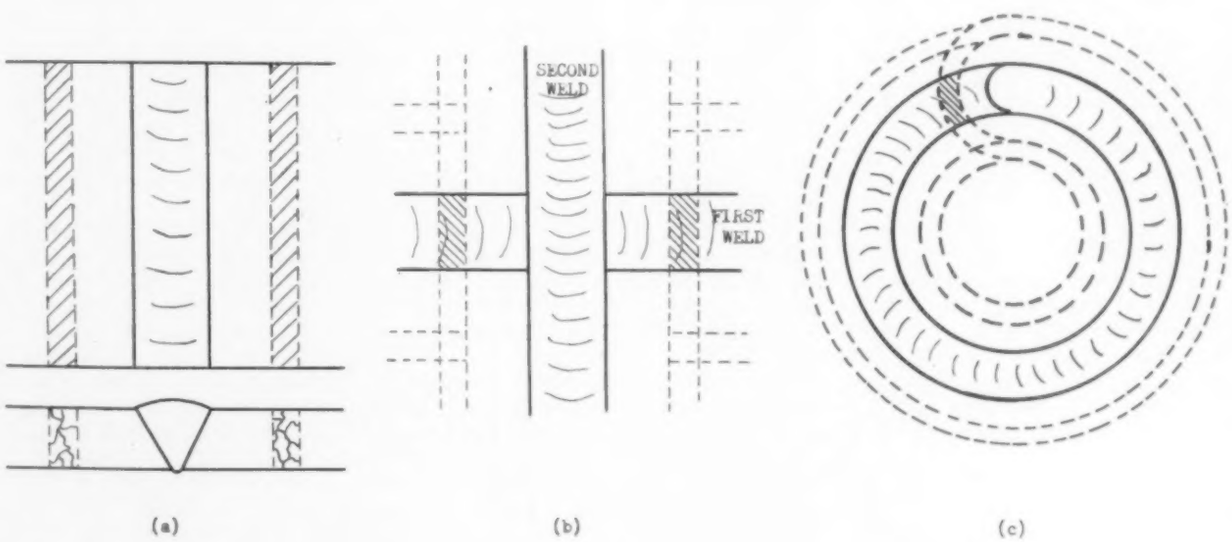

Fig. 50

(a) A butt weld in unstabilized 18–8
— — — — — — Boundary of zones heated between the upper and lower temperature limits of dangerous intergranular precipitation
The shaded zones are susceptible to intergranular corrosion
(b) Two welds intersecting in stabilized 18–8. The weld metal in the first weld is not stabilized and may be rendered susceptible to intergranular corrosion in the shaded zone heated by the second weld
(c) Circular weld made with unstabilized weld metal in stabilized 18–8. The weld metal may be susceptible to intergranular corrosion in the shaded zone beyond the end of the weld at the top of the diagram. Here the heat from the returning weld has reheated the weld metal deposited at the start of the weld to temperatures at which intergranular precipitation of carbide occurs. Similar conditions exist in pipe welds, if unstabilized filler metal is used. — — — — — — Boundaries of zones heated between the limits of temperature for dangerous intergranular precipitation of carbide

agents. The transgranular type is believed to be an instance of corrosion fatigue.

Both quenching and immunizing treatments, depending upon service, are used to relieve shrinkage stresses in welded 18–8 vessels. For example, welded molybdenum 18–8 vessels (Boiler Code Case No. 836) may be stress relief heat treated by:

(*a*) heating to at least 1950° F. for 1 hr. per inch of thickness, but never less than 15 min., cooling rapidly and uniformly, to avoid stress corrosion cracking, which might result from non-uniform cooling,

(*b*) heating to 1600–1650° F. sufficiently long to provide freedom from intercrystalline corrosion, cooling in a still atmosphere (not rapidly).

Immunizing treatment (*b*) yields lower internal stresses than quenching treatment (*a*) on account of the slower cooling rate, but, as we found in the discussion of the immunizing treatment, it lowers the general corrosion resistance.

CORROSION

By "general corrosion resistance" we mean corrosion that acts uniformly over the exposed surface and is not concentrated along the grain boundaries. All told, there are four types of corrosion that are important for 18–8.

1. General corrosion acting over the entire exposed surface. Boiling nitric acid (Huey Test) is a good test for general corrosion resistance, but if intergranular carbides are present the nitric acid may dissolve the carbides.

2. Intergranular corrosion. The test (Boiler Code Case No. 834) to determine whether welding has created susceptibility to intergranular corrosion is to boil the specimen 48 hr. in a solution containing 47 cc. conc. H_2SO_4, 13 gm. hydrated $CuSO_4.5H_2O$ per liter of solution. The reagent attacks the depleted solid solution at the grain boundaries. The specimen should be capable of bending without fissuring at the end of the test. The test may also be used to determine whether a steel is susceptible to carbide precipitation during welding. For this purpose the unwelded specimen is heated 1 hr. at 1200° F., which is supposed to duplicate the most severe effects likely to be encountered. The weld-effect test in A. S. T. M. Specification A 198–39 for Chromium-Nickel Steel Castings is similar but requires only 10 min. at 1200° F., followed by air cooling and metallographic examination for intergranular carbides, Fig. 49, may be substituted for the corrosion test.

3. Stress corrosion cracking.

4. Pitting corrosion. For some reason a reagent which has no effect on 18–8 may suddenly commence to corrode it at random points over the surface or at grease marks, or where the 18–8 is in contact with other materials. Holes are formed at the points of attack. Sometimes pitting corrosion occurs in 18–8 buried in the soil. Welding does not influence pitting corrosion unless the welder has carelessly ruined the surface.

At this point we may return to Fig. 47 (*b*), which we left in order to discuss the carbide question. The 18–8 containing 0.07% C has cooled below 900° C. and now reaches 650° C. Does the austenite commence to transform to ferrite? Not at all; during slow cooling through and below 650° C. to room temperature the austenite remains intact and non-magnetic. The atoms of the alloy are bonded tightly together and refuse to change to the alpha form unless they are kneaded by cold work; for example, cold rolling at room temperature. During cold rolling the planes of atoms are forced to slip on each other which provides the impetus necessary for the change of some of the austenite to ferrite. The ferrite is magnetic and accounts for the fact that cold worked 18–8 is attracted by a magnet. Welding the cold worked 18–8 converts the heat-affected zone to non-magnetic austenite. The regions below line $G_1S_1S_2$ contains alpha, therefore, only if the 18–8 has been cold worked. Any ferrite formed by cold work at temperatures below the line changes back to austenite upon being reheated above the line.

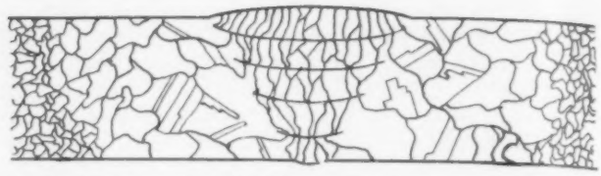

Fig. 51—Structure of a Multi-Layer Butt Weld in 18–8, Showing Absence of Grain Refinement of Previous Beads by Succeeding Beads

Note the growth of base metal crystals across the line of fusion and into weld metal. Thin beads may yield finer grain size in base metal and weld metal than thick beads

Cold or hot work is the only means of refining the grain structure of 18–8 in and near a weld, Fig. 51. Since the austenite does not transform to ferrite on cooling and reheating, the coarse grain structure near each bead and the dendritic structure of each bead itself are unaffected by the heat from a succeeding bead. If the bead is hammered while it is cold or hot, however, the high temperature from the next bead causes recrystallization of the cold worked regions with accompanying grain refinement provided cold working has been sufficiently heavy. Hot working or peening refines the grain size without the necessity of a subsequent pass. Grain growth is not a serious difficulty in 18–8 and peening seldom is performed, except to correct distortion in the first few beads.

Although the wrought forms of 18–8 are the most common, castings occasionally are welded. Besides the usual precautions of removing all traces of a defect before repair welding, it is important to heat treat the welded casting by cooling rapidly from 1100° C. Quenching stresses in 20% Cr, 9% Ni castings may be relieved by heating to 425° C. To avoid intergranular precipitation of carbides the time at 425° C. should not exceed 2 hours. Some castings and also some wrought 18–8 contains high sulphur (0.30% S with 0.60% Mo) or selenium (0.30% Se, 0.15% P) to provide free-machining or non-galling characteristics. Owing to their volatility and tendency to oxidize, these elements increase the difficulty of making a sound weld.

An alloy having similar characteristics to 18–8 is 25–20, which contains 25% Cr–20% Ni. The increased chromium and nickel contents of 25–20 reduce the speed of carbide formation, compared with 18–8, and also provide additional chromium to combat depletion in the event that carbides precipitate. Time is an important factor in carbide precipitation in 18–8. The shorter the time of heating, the higher is the temperature at which the precipitation begins. Thus it has been found that the temperature of maximum precipitation effect decreases from 650–750° C. for a heating period of 30 secs. to 450–600° C. for a heating period of 1000 hours. Some authorities maintain that if extremely short heating periods are involved, as in the heat-affected zone of a spot weld in 18–8 sheets, the chromium and carbon atoms do not have time to combine and there is no intergranular precipitation.

Rapid spot welding or "shot" welding as it is often called, is imperative for 18–8. If the weld is made sufficiently rapidly, the zone heated to carbide precipita-

tion temperatures may not reach the outer surfaces of the overlapping sheets. Consequently, unless the corroding agent penetrates between the sheets, there is no intergranular corrosion around the spot weld in service. To keep the surfaces of 18–8 sheets cool during seam welding, the sheets are held under water during welding. The rapid cooling may prevent the zone of dangerous temperatures from reaching the surface of the sheets and the time within the dangerous range may be sufficiently short that no nuclei of carbide particles have yet formed. Copper backing strips may be used in butt welding 18–8 with covered electrodes for the purpose of chilling the heat-affected zone and so suppressing intergranular precipitation of carbide. The backing strip also permits the use of high currents to secure root fusion without formation of icicles on the reverse side.

STAINLESS CLAD

An application of 18–8 that frequently requires welding is stainless-clad steel, which is mild steel with a surface layer of 18–8 amounting to 10% or 20% of the thickness. Besides the usual precautions to prevent intercrystalline precipitation of carbide, welding of stainless-clad steel necessitates precautions against dilution of weld metal by underlying steel. When a bead of 18–8 is deposited on mild steel, pick-up of iron and consequent reduction of chromium and nickel content of the weld metal is unavoidable (see section on "Pick-Up," Part VI, Vol. II). To reduce pick-up it is necessary to deposit several beads on the stainless side. In this way the last beads to be deposited fuse into 18–8 and diluted 18–8 weld metal and not into mild steel. Substitution of a 25–20 electrode for 18–8 also reduces the effect of pick-up. In depositing any stainless filler rod, it should be remembered that loss of chromium by oxidation is inevitable if a long arc or oxidizing flame is used, and that a reducing flame is undesirable for it increases the carbon content of the deposit. Grease or oil, if allowed to remain on the edges to be welded, also increases the carbon content of the weld.

The junction of an austenitic steel with plain-carbon steel consists of metal having an intermediate composition. The junction between mild steel and stainless cladding is sharp, but between mild steel base metal and metal from a stainless steel electrode there is a junction zone of microscopic width in which all compositions between mild steel and the diluted weld metal are represented. At room temperature the mild steel is ferritic, the weld metal is austenitic. Between the two a region of martensite is observed in accordance with the fact that when alloying elements that cause ferrite to give way to austenite are added to mild steel, there is a range of compositions between the ferritic and austenitic stages in which martensite is found at room temperature after cooling at ordinary rates. The martensite changes to ferrite if equilibrium conditions are established by extremely slow cooling. The appearance of martensite between mild steel and a stainless steel weld deposit thus may be expected. Experiment shows that, although the martensitic zone is hard, it is thin and does not injure the toughness of the joint.

STAINLESS IRONS

In addition to the chromium-nickel stainless steels, the stainless irons, Table 2, also are important for welding. Grades 1 and 2 with 10 to 14% Cr may be hardened in the same way as medium-carbon, and plain-carbon steels. Since the martensitic stainless irons harden at relatively slow cooling rates, preheating is important to prevent hard zones and possible cracking, and annealing after welding is advisable for high ductility.

Table 2—Some Types of Corrosion-Resisting Chromium Steels Listed in A. S. T. M. Standard A 176–39

Grade	Type No.	C, Max.	Mn, Max.	S, Max.	P, Max.	Si, Max.	Cr	Ni, Max.
1	403	0.12	0.60	0.030	0.030	0.75	11.50–13.00	0.60
2	410	0.12	0.60	0.030	0.030	0.75	12.00–14.00	0.60
3	425	0.12	0.60	0.030	0.030	0.75	14.00–16.00	0.60
4	430	0.12	0.50	0.030	0.030	0.75	16.00–18.00	0.60
6	446	0.35	0.50	0.030	0.030	0.75	23.00–30.00	0.60

Except that the critical range of the martensitic stainless irons is higher (950° C.) than for plain-carbon and low-alloy steels, and the eutectoid carbon content is only 0.3%, the principles involved in welding are the same as those outlined in Part VI, Vol. II.

Entirely different behavior is exhibited by the 15–18% Cr irons, which have been used for welded tanks to hold nitric acid. These alloys, Fig. 52, consist of ferrite and carbide (Cr_4C) below the critical range. Above the critical range they consist of ferrite and austenite. Upon being quenched, the austenite changes to martensite, but the alloy as a whole is not hardened to a great extent because perhaps half of the alloy consists of ferrite, which remains soft throughout the quench.

Although there is no danger from hardening during welding the 15–18% Cr irons, there are difficulties from

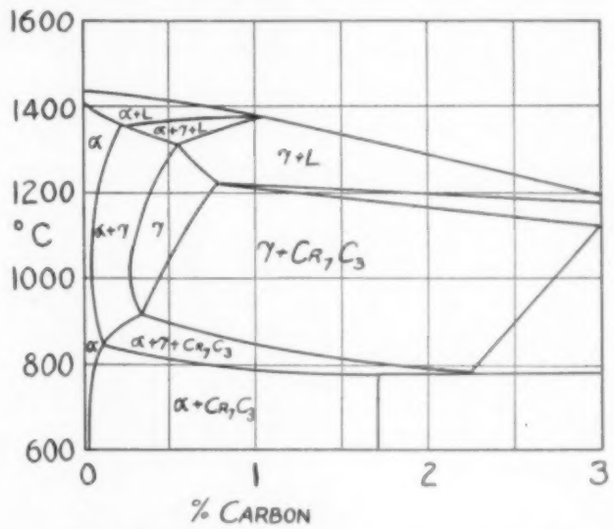

Fig. 52—"Stainless-Iron," Carbon Phase Diagram for 15% Cr Alloys (Tofaute)

The significance of the diagram for welding can be appreciated by studying the 0.1% C alloy during heating and cooling. At room temperature the stainless iron consists of ferrite and carbide ($\alpha + Cr_7C_3$). During heating above about 800° C. some austenite appears. The austenite contains more carbon than the ferrite. In fact the austenite forms through simultaneous solution of carbide and transformation of alpha to gamma in the immediate vicinity of the dissolving carbide. At 900° C. the stainless iron consists of low-carbon ferrite and higher-carbon austenite. As the temperature rises to 1000° C. the austenite and ferrite both become less concentrated in carbon which can happen only by higher-carbon austenite diluting itself by absorbing some of the lower-carbon ferrite. At still higher temperatures the process is reversed, ferrite replacing more and more austenite until just below the melting range the stainless iron is completely ferritic, if equilibrium has been achieved. During cooling the reverse process is set in motion. At about 850–900° C. the austenite decomposes to ferrite and carbide during slow cooling, as in unalloyed steel. The carbide is spread through the space previously occupied by the austenite. Fast cooling may preserve the austenite to low temperatures, again as in plain-carbon steel, where it may transform partly to martensite

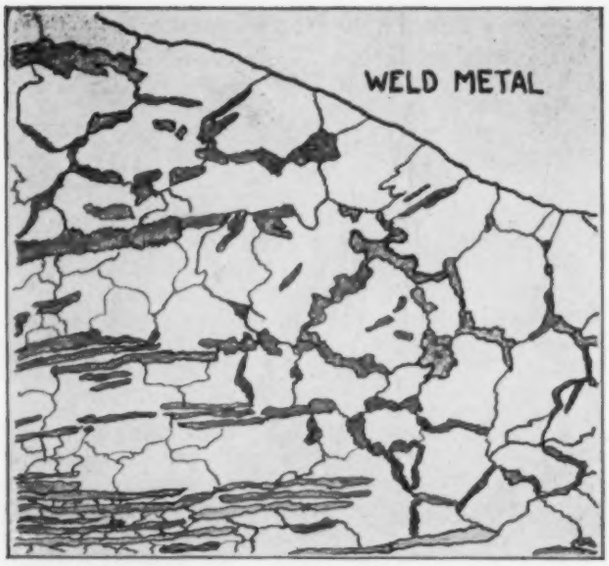

Fig. 53—Microstructure of a Weld in 17% Cr Iron, Showing Coarse Grains in the Heat-Affected Zone (Traced from a Micrograph by Emerson)

The customary wrought structure of 17% Cr stainless iron is shown at the lower left, and consists of fibers of austenite (shaded) elongated in the direction of rolling, embedded in small grains of ferrite. Near the fusion line the ferrite grains have grown, and the austenite has become intergranular, a structure that has very low notch impact value at room temperature

grain growth in the heat-affected zone close to the weld, Fig. 53. In the annealed condition the carbide in 16% Cr iron is arranged in bands through the hot-rolled plate, corresponding to segregation in the ingot. During welding the bands of carbide in the regions heated above the critical range react with ferrite to form bands of austenite. Little grain growth occurs except in the region heated to 1200° C. or over during welding. In these zones the bands are reduced in width as indicated in Fig. 52, and are unable to restrain the growth of the ferrite grains. The ferrite grains accordingly grow and often become visible to the unaided eye. During cooling after welding the large ferrite grains undergo no transformation and maintain their exaggerated dimensions. The behavior of the austenite during cooling is immaterial but it may be mentioned that the austenite changes to martensite or ferrite and carbide, depending on the rate of cooling.

Instead of the high notch impact value of fine-grained 16% Cr iron, the coarse-grained heat-affected zone and weld metal have practically zero notch impact value at room temperature. The brittleness is of the last type discussed in Part III, Vol. II; that is, brittleness due to a low ratio of tensile strength to shear strength. The notch impact value of mild steel drops suddenly to nearly zero when the temperature is lowered below room temperature. The sudden drop occurs at relatively high temperatures for coarse-grained mild steel (0° C.), but at lower temperatures (−100° C.) for fine-grained steels of practically the same composition. The 15–18% Cr irons behave similarly. Coarse-grained material is notch brittle at room temperature, but is tough at 200° C. or above. Fine grained 18 Cr iron is tough even at room temperature, but loses its notch impact value at sub-zero temperatures. The chromium content at which the coarse grains lose their notch impact value at room temperature is not clearly defined, but is between about 15% and 17% Cr depending on grain size.

The coarse-grained zone can be prevented in two ways. First, 0.1% nitrogen may be added to the alloy; the nitrogen prevents exaggerated growth in the heat-affected zone, and if it is added also to the weld metal, forces it to solidify as fine grained. Second, the weld may be hot peened. Unfortunately, hot peening is seldom applicable and is rarely reliable. Any attempt to cold peen the coarse-grained zone would be disastrous. Preheating of 18% Cr iron above the temperature at which it behaves in a brittle manner when in the coarse-grained condition is advisable during welding.

Questions

1. Is carbon segregation the reason for carbides precipitating in the grain boundaries of 18–8 instead of precipitating uniformly throughout each grain?
2. Under what conditions of time, temperature and composition does intergranular carbide precipitation occur in corrosion resistant steels? Why does welding provide favorable conditions for intergranular precipitation of carbides in 18–8?
3. State five remedies for intergranular carbide precipitation during welding.
4. Why should a stabilizing element be present in weld metal for stabilized 18–8? Is there any justification for using unstabilized weld metal with stabilized base metal or vice versa?
5. What heat treatments are used for welded 18–8 at present? Do the heat treatments remove shrinkage stresses or affect the microstructure of the welded zone? Why must shrinkage stresses be removed to prevent stress corrosion cracking in parts that operate under stress in any event?
6. What is the principal difficulty in welding stainless iron containing 16 to 18% Cr? Why is it difficult to overcome the trouble?

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The Best Joint Designs for Silver Alloy Brazing

By F. T. Van Syckel†

IN LESS than ten years low-temperature brazing with silver alloys has grown from a little-known metal joining process to one that is now used in industrial plants almost everywhere. This rapid growth is connected very closely to the development in the Handy & Harman laboratories of two low-temperature silver alloys —one composed of 15% silver, 80% copper and 5% phosphorus which joins non-ferrous metals only at 1300° F. and the other containing 50% silver, 15½% copper, 16½% zinc and 18% cadmium which has the extremely low flow point of 1175° F. and is equally effective for joining non-ferrous, ferrous or dissimilar metals.

When these two proprietary alloys were first introduced they, as well as other silver solders, offered advantages that were new to most industrial manufacturers. At about the same time the big increase in the use of sheet metals, stampings and tubing gave the opportunity needed for these alloys to prove their value. Their use spread rapidly, mainly because they filled three primary manufacturing needs—the joints they made were strong and reliable, their fast brazing action speeded up production and the cost of brazing by the low temperature method was surprisingly low.

With increased use, the types of work brazed by these alloys have spread rapidly and, as new applications have come up, the subject of joint design has become a more and more important one. In reality, joint designs for silver alloy brazing are influenced to a great extent by the unusual flowing qualities of these brazing alloys. When heated to their flow points, they are extremely liquid and penetrate very quickly into narrow openings. Then, if metal surfaces are clean and properly protected by flux from oxidizing during preheating, capillary action spreads the brazing alloy throughout a joint rapidly and completely. Extreme fluidity, rapid penetration, low working temperatures and the small amount of alloy required to make a joint are responsible for the fast production and low costs this method of joining metals makes possible.

The Clearance Required

To get the full benefits offered by silver alloy brazing, the amount of clearance required is most important and this subject has been given a great deal of attention. Drive fits stop the brazing action and leave room for but little more than a small fillet to give strength. Fits that have excessive clearance result in joints with strength below the maximum. In the laboratory and in the field it has been determined, after extensive testing, that the best results are obtained when clearances between surfaces to be joined are held around 0.001 to 0.003 inch. Figure 1 shows the effect clearance has upon tensile strength. It also shows that silver alloys, which in cast form have high tensile strengths of from 40,000 to 60,000 lb. per sq. in., have the unique ability to make joints of still higher strength when proper clearances are maintained. For example, an extreme difference is illustrated in Fig. 1 where with close clearances the tensile strength of a joint reached 134,000 lb. per sq. in. This is due to diffusion of the brazing alloy into metal surfaces leaving but little, if any, of the alloy in true cast form. As clearances increase, strengths drop closer to the cast form strength of the brazing alloys, which in themselves have excellent physical characteristics. Hence, for the best type of joint, proper clearances should always be maintained. The clearances required can be readily and inexpensively maintained in manufacturing.

Types of Joints

With these fundamental principles as a background, we are ready to consider the types of joints which have been found most practical to use in regular production. Briefly, there are three general types—butt, scarf and lap or shear. The lap or shear type is the design most commonly used and recommended, although the others can be used satisfactorily.

Butt Joints.—There are applications where the double thickness of a lap or shear type joint is undesirable and well-made butt joints can be used with good results, if a few precautions are watched closely. The surfaces to be joined should be cut or machined square and even so that, when pressed together, they will provide the close

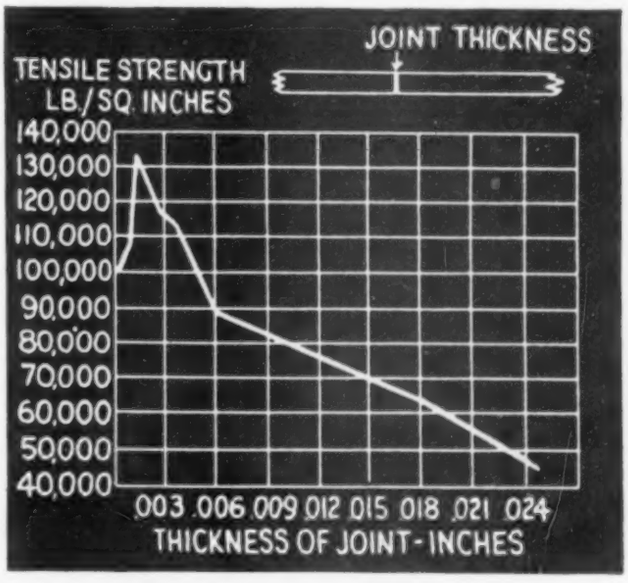


Fig. 1—The Relation of Joint Thickness to Tensile Strength, Based Upon Butt Joints of Stainless Steel to Stainless Steel

† Handy & Harmon, New York, N. Y.

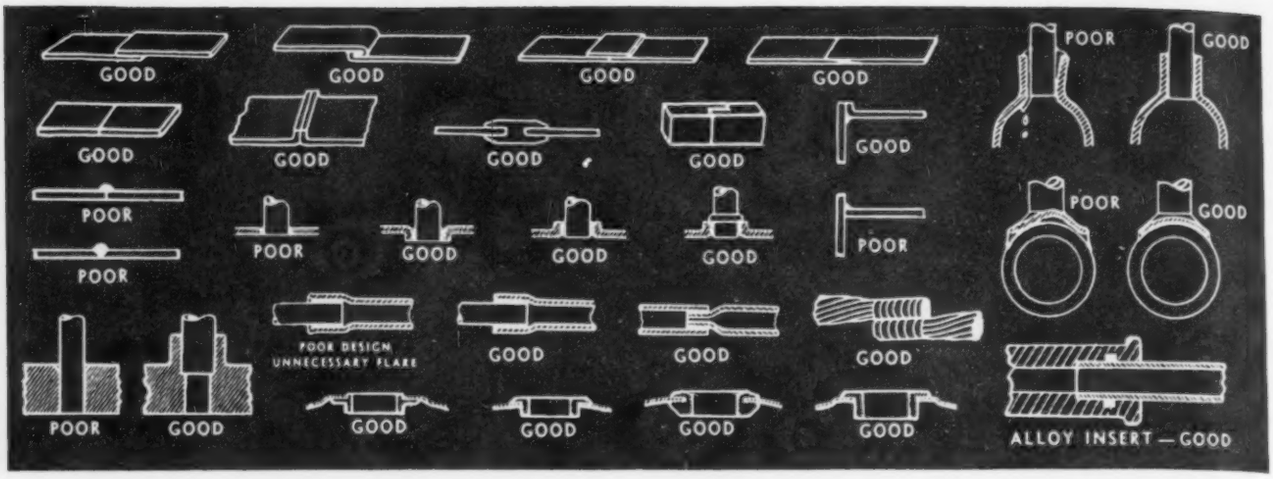


Fig. 2—Good and Bad Joint Designs

clearances required for high strength. Joints of this kind, made under production conditions, are strong and reliable when proper care is taken.

Scarf Joints.—This is another form of butt joint which may be used, in which joint surfaces are beveled to an angle of less than 90°. This design provides larger joining surfaces than butt construction and gives high strength without making joint thickness greater than that of the metals joined. Parts can be readily held in place with clamps while brazing. Joints of this type are used on such work as the joining of band saws, pipe fabrication, tank construction, etc.

Shear Type Joints.—They are the most satisfactory and most generally used because it is possible to incorporate any desired factor of safety by varying the lap area. Due to the small area of alloy exposed, lap joints also offer better resistance to corrosion. Joints are readily held in place for brazing and you have good control of tolerances. In joining flat parts, a little pressure assures complete bonding. Where tubular members are joined, pressure cannot be exerted and clearances and capillary action become the controlling factors.

Shear Depths

The depth of shear required will vary according to the strength of the metals to be joined and the factor of safety wanted. The following formula shows a commonly used method of figuring shear depths.

FORMULA

X = (unknown)—depth of shear
D = Shear diameter
T = Tensile strength of weakest member
W = Wall thickness of weakest member
Y = Factor of safety
L = Shear strength of silver brazing alloy

$$X = \frac{W\,(D-W)\,YT}{LD}$$

EXAMPLE

Length of shear depth necessary when joining $^3/_4$″ — 0.064″ wall thickness copper tube to $^3/_4$″ steel tube sheets.

X = Unknown
D = 0.75″
T = 33,000 psi annealed value copper
W = 0.064″
Y = 5. (Note: this value is used on this particular job in that the thickness of the tube sheet lends itself to this factor. Where shear depths are limited a smaller safety factor will prove satisfactory.)
L = 25,000 psi shear value of silver brazing alloy. (Note: this is an arbitrary minimum value which can be expected from all silver brazing alloys containing appreciable amounts of silver.)

$$X = \frac{0.064 \times (0.75 - 0.064) \times 5 \times 33{,}000}{25{,}000 \times 0.75} = 0.386''$$

depth of shear

A similar method can be used with flats. In this case the formula becomes $X = \frac{YTW}{L}$

Example: Length of shear necessary when joining 0.050 inch annealed Monel metal sheet to a stronger material or material of equal strength.

X = Unknown
T = 70,000 psi (annealed Monel metal sheet)
W = 0.050 inch
Y = 4
L = 25,000 psi (Note: this is an arbitrary minimum value which can be expected from all silver brazing alloys containing appreciable amounts of silver.)

$$X = \frac{4 \times 70{,}000 \times 0.050}{25{,}000} = 0.56 \text{ inch—length of shear}$$

Applying the Alloy

After a type of joint has been selected there are many ways of adapting it to the general design of a part or piece of equipment. In Fig. 2 a number of basic designs are shown which are in general use. Note particularly the high hub flange shown in the lower left-hand corner. To make the joint marked "poor" it would be necessary to heat the heavy mass the tube is joined to all the way through. This would be difficult and slow. By using the construction marked "good" the relatively thin high hub can be rapidly heated and joined to the tube without bringing the heavy section up to brazing heat. Just above these flange designs are two illustrations marked "poor." The top one shows a bead of alloy along the joint. This requires far more alloy than is necessary and the bead, which in reality is a casting, would not give as high strength as you would secure if a thin film of alloy were flowed between the surfaces to be joined. Likewise the V-shaped groove below gives the

strength of a casting rather than the higher strength a thin film assures after it has alloyed with the metals joined. In the upper right-hand corner are two examples of poorly fitted joints. While the poor fits can be brazed, it pays to fit joints properly and usually speeds up the brazing operation. Some of the joints shown are simple joints—others are particularly suited to a definite way of applying the brazing alloy. In designing a brazed joint, therefore, it is important to give some thought to how the alloy is to be applied. In this connection an important factor is that silver alloys are readily rolled into sheet and drawn into wire of practically any size. You can choose a form suited to any particular job, keeping in mind that there are three general methods of applying the alloy to the work: (1) by hand feeding; (2) by preplacing the brazing alloy in or around the joint; (3) by providing a groove or reservoir in which the alloy can be preplaced.

Under production conditions, on a good percentage of the work that is done, the brazing alloys are applied by hand. This holds true where quantities are large or small. The size of wire or strip most practical to use should be in such proportion to the size of the joint that the alloy will melt quickly and give enough alloy to make the joint without requiring too great a length of rod, wire or strip. The use of too large a size usually results in melting an excess of alloy. It is wasteful and can spoil the appearance of a finished joint. Figure 3 shows an excellent example of how high production set-ups use hand feed in the refrigeration field.

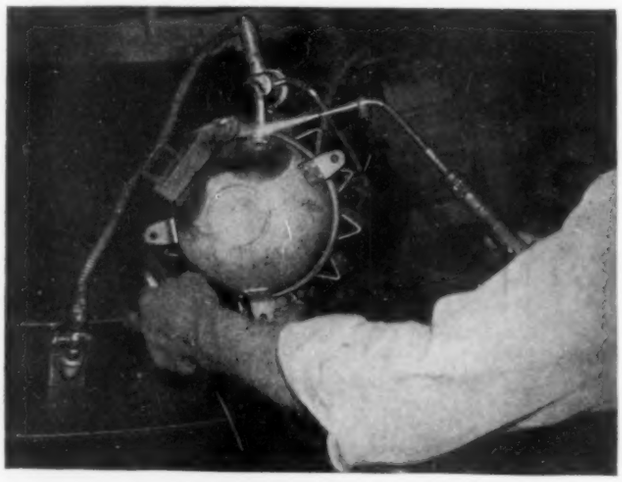


Fig. 3—On Production Set-Ups Like This, Brazing Time per Joint Is a Question of Seconds. The Table Carrying Refrigerator Compressor Housings Rotates and the Alloy Is Applied by Hand

These brazing alloys also may be preplaced in making either flat or tubular joints and can be used in the following forms:

1. Inserts of sheet and flat washers.
2. Rings of round or other shaped wire.
3. Alloys may be sprayed on surfaces.
4. Filed or powdered brazing alloys can be sprinkled on or mixed with flux and painted on the joint.
5. Surfaces can be "tinned" with brazing alloy by dipping or other methods.

Inserts of sheet or washers and rings of round or other shaped wire are the forms most generally used. A good example of a thin sheet insert is shown in Fig. 4. In building this switchboard bus system silver alloy brazing replaced riveting and sweating with soft solder and gave savings that were very worth while. The sheet of alloy 0.010 in. thick is inserted between the two bars to be joined and clamped in place. The joint is then heated with an oxyacetylene torch until the brazing alloy flows. The finished joint is strong and in service will not heat or oxidize. It is neat in appearance and with the lap joint used electrical conductivity is higher than the copper itself. On work like this, due to the small lap shear area needed, worth-while quantities of copper can often be saved. Alloy inserts of this type are used to join bus systems between generators and switchboards, for taps on transformers, seams in tanks and in many other spots where pressure can be applied to the assembled joint while heating.

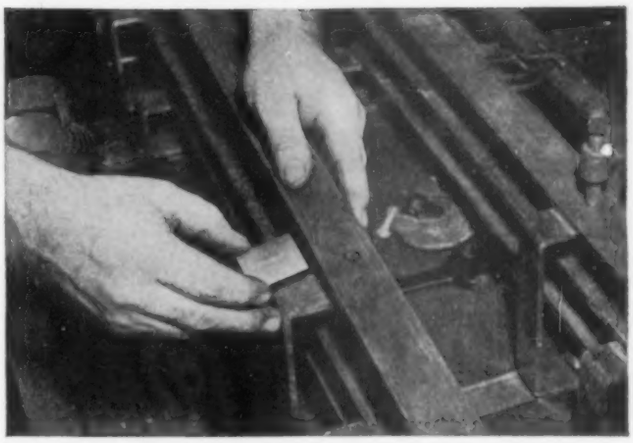


Fig. 4—This Insert of Sil-Fos Is 1½ In. Square and 0.010 In. Thick. It Cost Less Than 2¢ and Makes a Strong, Neat, Highly Efficient Electrical Connection

Washers of brazing alloy have proved effective in joining parts to flat and curved surfaces. The spud application in Fig. 5 is typical. Usually washers are used where pressure can be applied. As the brazing alloy melts, parts settle into place, giving the close clearances required for the best joints. While washers do a very satisfactory job, it is best to confine their use to designs where definite advantages are gained. Small work where parts can be heated uniformly often can be brazed more economically by using less costly rings of brazing alloy wire. Other work, where heat cannot be evenly distributed and the alloy must be heated in sections or increments, is better suited to washers.

The number of ways of applying rings is practically endless. The main points to keep in mind are to provide the proper space into which the alloy can flow and to

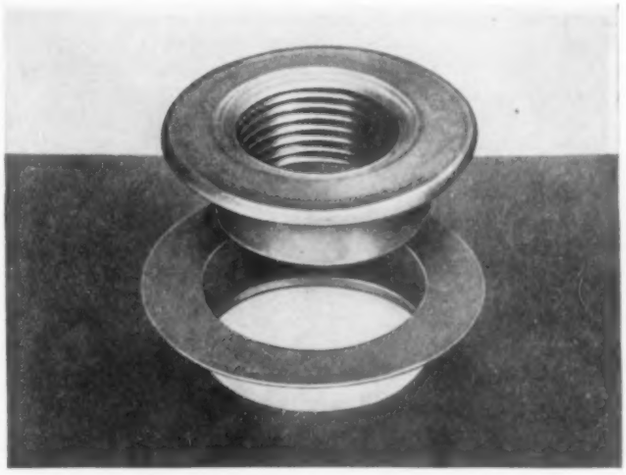


Fig. 5—Washer Applications of This Type Make Reliable Connections for Joining Pipes to Tanks. A Little Pressure Applied While Heating Assures Close Fits and High Strength in the Joint

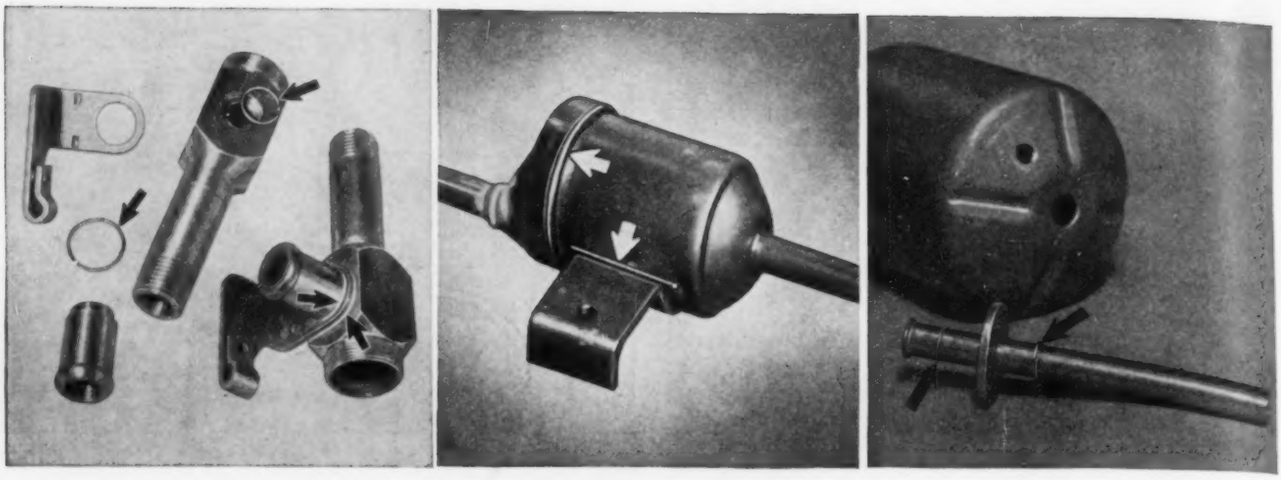


Fig. 6

(*a*) This auto heater valve is brazed in an oil fired furnace. Two rings of Easy-Flo are used—one joins the bracket to the valve body—the other the hose connection to the bracket. Brazing rate 2200 per 8 hour day

(*b*) The header and bracket on this small dehydrator are joined to the body by a ring of Easy-Flo and a piece of straight Easy-Flo wire. Brazing rate 400 per hour

(*c*) Two rings of Easy-Flo wire are used to connect the center tube of this oil filter to the shell. One ring joins the washer to the shell—the other joins the tube to the washer

make sure that there is proper venting so that the molten brazing alloy can float out excess flux and also allow any gases formed in preheating to escape. Following these precautions does away with flux inclusions and gas pockets which can be the cause of leaking joints. The design of some joints makes it practical to use two or more rings in a single joint. Three examples of work of this kind are shown in Fig. 6.

Another very important use for low-temperature brazing is the joining of pipe and tubing. Because pressure cannot be applied to work of this type, clearances between the surfaces to be joined should be rigidly held to the limits which assure the best strength.

One type of tubular joint is to bell out one end of a tube and, after proper cleaning and fluxing, to slip another tube end into it. This construction is commonly used in the refrigeration and air-conditioning industries. Brazing can then be completed by torch with the alloy applied by hand or preplaced in the form of rings. Slip-type fittings for joining tubing also are on the market and work very well with these alloys.

Where pipe or tubing is to be joined, or pipe or tubing is to be joined to tube sheets or headers, the reservoir type of preplacing can be used. Designs of this kind are provided with a groove into which the brazing alloy is inserted. The location, size and shape of the groove will depend upon the size of the joint members and the design of the completed assembly. Figure 7 shows two common methods of preplacing the alloy. If the alloy is placed at *a* the assembly must be heated so that the flow will be vertically downward. It is good practice to extend the alloy insert above the groove so that the joint is made and the groove is filled at the same time. If it is placed at *b* the heating may be done in any position, as capillary action will pull the alloy in all directions and spread it throughout the joint area. In either case, the depth of shear area, exclusive of the depth of the groove, should provide the necessary factor of safety to meet any requirement for strength.

Preplacing fits in well on many production set-ups. It offers advantages in making flat and tubular type joints because it permits accurate control of alloy cost per joint, assures a complete flow of alloy throughout the joint area, acts as a temperature guide and, as there is no run-off, aids in making better-looking joints. Because preplacing relieves operators from feeding the alloy, they have a better opportunity to control heating when it is done by torch or other manually controlled methods.

The Method of Heating

Whether or not a joint should be designed for hand application or preplacement of the brazing alloy depends on a number of factors, including the method of heating. There are several heating methods which can be used satisfactorily. The most widely used are torch heating, furnace heating, electrical heating and heating by dip methods. The one best suited to any particular work will depend upon the design of the part, the quantity of work, size of individual units and whether the work is to be done in the shop or the field.

When heating is done by torch, most types of joint design can be used and the alloy can be applied by hand or can be preplaced. To assure the best results there are a number of points, however, that need particular attention. Fast heating is preferred and the oxyacetylene torch is therefore recommended, although gas and oxygen and, for some work, gas and air can be used. A neutral or reducing flame works best. The work should be heated

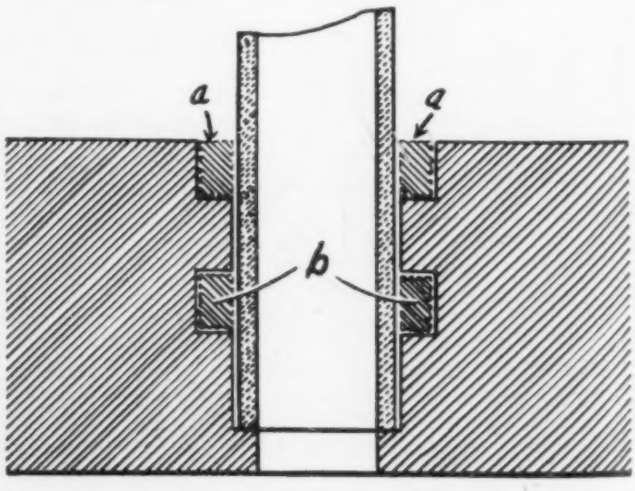


Fig. 7—Two Typical Methods of Applying Inserts in Joining Tubular Members or in Joining Tubular Members to Tube Sheets or Headers

slightly above the flow point of the brazing alloy. Heat should be uniform and direct impingement of the flame on the brazing alloy avoided. Large surfaces should be heated well away from the joint. In joining dissimilar metals, the more rapid conductor will require more heat. Both metals should come to brazing heat at the same time. If metal thicknesses differ, concentrate heat on the heavier section. Recent development of multi-flame tips has speeded up heating and made it easier to heat uniformly. Where alloys are preplaced, there is usually visible evidence that the alloy has flowed, but it is well to make certain that sufficient heat has been applied to assure a complete flow. Before a joint is quenched, enough time should be allowed to make sure the brazing alloy has set. Figure 8 shows a double tipped torch in use.

Where there are quantities of similar parts to be joined and especially where parts are medium or small in size, furnace brazing is a fast and economical way of heating. Oil, gas or electrically heated furnaces can be used and parts should be designed with the brazing alloy preplaced. Fast heating is desirable and a non-oxidizing atmosphere is preferred. The correct temperature to use will depend on the size of the work, the quantity of parts heated at one time and the size of the furnace. Figure 9 shows how weights are sometimes used to give pressure on joints brazed in this way.

Incandescent carbon heating offers the advantage of rapid heating under pressure. It is used mostly for joining flat parts, although it can be applied to other shapes. These brazing alloys can be preplaced or hand fed. Among the important jobs done by this method in large quantities is the joining of taps to transformer windings. Figure 10 shows a portable machine used for this purpose.

Electrical induction heating, while comparatively new, as applied to brazing, offers a number of advantages. The rapid localized heating it provides has been responsible for the growing interest in it as a means of heating. Joints must be designed with the alloy preplaced and parts having a uniform shape and thickness are best suited to this method. In Fig. 11 cemented carbide cutting edges are being joined to a reamer body.

Dip brazing offers two ways of heating: (1) the metal bath and (2) the chemical bath. The metal bath requires that parts be held in brazing position and dipped into molten brazing alloy. Brazing by this method is confined mostly to small work and is used on such work as joining fine wires. Crucibles for holding the molten alloy may be heated by gas, oil or electricity.

Fig. 8—Multiple-Tip Torches Promote Fast and Uniform Heating. The Double Tip Torch Above Is Being Used to Join Special Fittings to Tubes of a Hot Water Heating Element in a Household Furnace

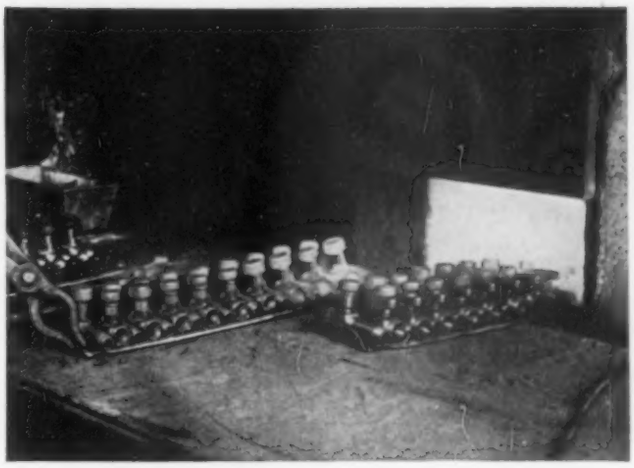


Fig. 9—Weights Are Used to Hold Parts Together While They Are Heated in This Oil Fired Furnace. As the Alloy Ring Flows, the Weights Squeeze Out Excess Alloy to Make a Close Fit Between Parts

Heating by chemical bath offers the advantage of fast, uniform heating and also provides protection from the oxidizing effect of the atmosphere. The salt solutions used are usually heated in an electrically operated furnace. Joints must be designed for preplacing and work should be supported in suitable jigs. The oil filter job in Fig. 12 shows a typical high production salt bath brazing set-up.

Electrical Conductivity

The high electrical conductivity of joints brazed with silver alloys, as compared to base metal joints, makes them particularly adaptable for use in connection with electrical equipment where conductivity is an important factor.

For example, tests show that with a lap of only $1^1/_2$ times the cross-sectional area, copper to copper joints made with these low temperature alloys have approximately 6 to 7% less resistance than the copper joined. This is due greatly to the increased lap area and the greater metallurgical contact in this type of joint. Similar tests on butt joints show resistances of from 4 to 18% more than copper. These figures will vary with the length of conductors and the distance between joints. Lap joints, therefore, can be used in electrical designs without increasing resistance in a conductor and butt joints where slightly higher resistance has no detrimental effects.

Strength at Elevated Temperatures

Extensive tests have been made to determine the effect of elevated temperatures on silver alloy brazed joints. Figure 13 shows the results of one series of tests. The indication, as other tests also have shown, is that joint strength tends to fall off regularly up to about 700° F. when the decrease becomes more rapid. Under many conditions, joint designs can be made with factors of safety which give sufficient strength for a great many elevated temperature uses.

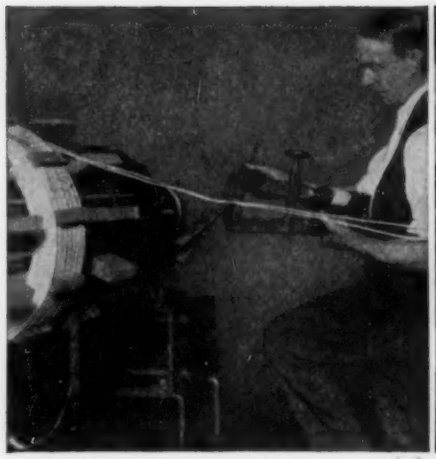


Fig. 10—A Portable Incandescent Carbon Heating Unit Joining Taps to Transformer Windings. The Alloy is Applied by Hand

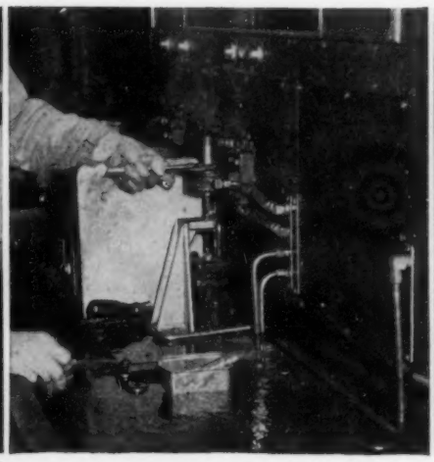


Fig. 11—Brazing Cemented Carbide Tips to a Reamer Body with Easy-Flo No. 3

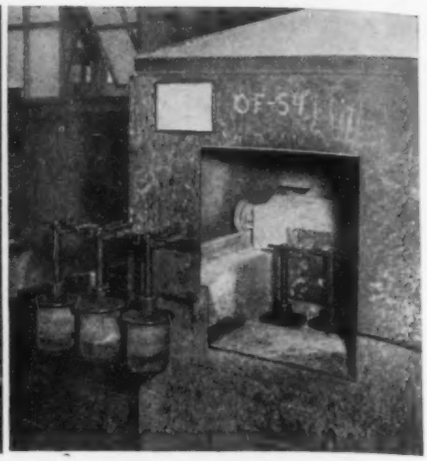


Fig. 12—This Salt Bath Brazing Set-Up Heats Three Oil Filters at One Time While Three Others Cool on the Rack to the Left

The Importance of Flux

In the foregoing we have been primarily interested in joint design and little or nothing has been said of the importance of flux. Fluxing is, however, a vital part of the low temperature silver alloy brazing process and the right or wrong use of flux can easily be the deciding point between good and bad work. Flux is used for three reasons—(1) to prevent oxidation; (2) to dissolve oxides which may form in preheating and (3) to assist in the flowing of the brazing alloy. To be most effective the flux should be liquid and fully active at the time the brazing alloy flows so that clean, oxide free surfaces are provided over which the alloy can flow without interruption. Such a flux has been developed and it should always be used with low temperature silver brazing alloys. It starts to melt and dissolve oxides at 800° F. and is extremely liquid and active at 1100° F. As it is stable to 1600° F., it works well over the entire silver alloy brazing range. The brazing alloy should always be protected with flux too.

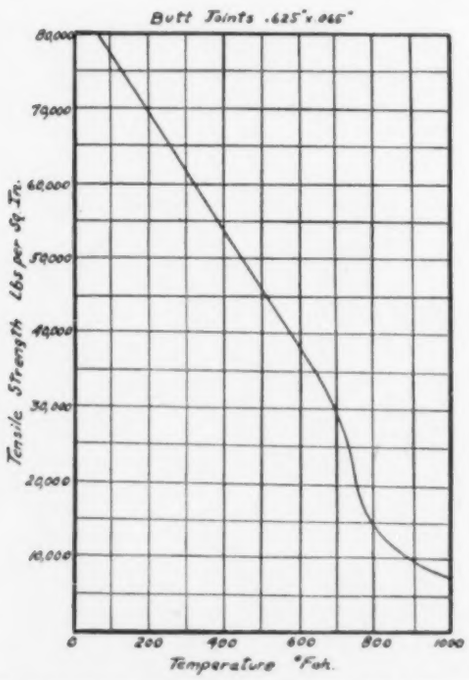


Fig. 13—The Effect of Temperature on Stainless Steel Silver Brazed Joints

Conclusion

From this review of points influencing joint design, it is evident that there are a few primary factors that should always be considered if the best results are to be secured. The features which every design should take full advantage of are: Low operating temperatures, free flowing qualities, rapid penetration and the small amount of alloy needed to make a joint. To make full use of these features is mainly a question of selecting a type of joint, using the right clearances, fluxing and applying the alloy properly, and heating uniformly and rapidly. The final result will be strong, ductile, leak-tight joints produced at low cost.

A large part of the laboratory and field development work which has accompanied the rapid increase in the use of these two alloys has been carried on with the help of Handy & Harman metallurgists and engineers. A wealth of information has resulted covering a wide range of applications. They are always glad to extend to you the benefits that can be gained from this data and experience.

Welding for Stiffness

By G. G. Landis*

THE principal function of stiffness in a structure is to resist side sway from wind or from earthquake. If the lateral force is operating from the left toward the right, as shown in Fig. 1, joints *A* and *D* are in compression and joints *B* and *C* are in tension. If the lateral force is operating toward the left, Fig. 2, joints *A* and *D* are in tension and joints *B* and *C* are in compression. Therefore, when welding for lateral stiffness, all joints must be able to resist both tension and compression, while when welding for continuous action only, top joints are always in tension while bottom joints are always in compression.

* Chief Engineer, The Lincoln Electric Co., Cleveland, Ohio.

Figure 3 shows a 24-inch, 74-pound beam intended for lateral stiffness (compare this with Fig. 4). The joint *A* is in compression. If the beam butts the column perfectly, the compression can be taken by bearing of the beam flange against the column. If this bearing is imperfect due to the beam being cut ragged or if the beam is not pushed up tight against the column, the fillet welds shown in Figs. 5 and 6 will transmit 45,000 pounds, or 90,000 pounds, respectively, in compression just as well as in tension, since the welds are fillets. The butt welds shown in Figs. 7 and 8 have greater compression strength than the tension values as normally calculated, since the unit stress allowed for compression is 18,750 pounds per square inch against 16,250 pounds per square inch for tension.

Figure 3 shows an erection clearance at *C*. If this clearance were at *A* instead of at *C* (see Fig. 9) and a plate connection of the type shown in Figs. 11 or 12

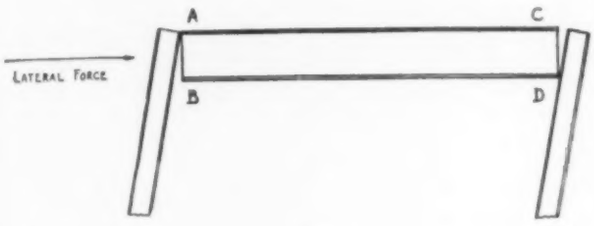


Fig. 1

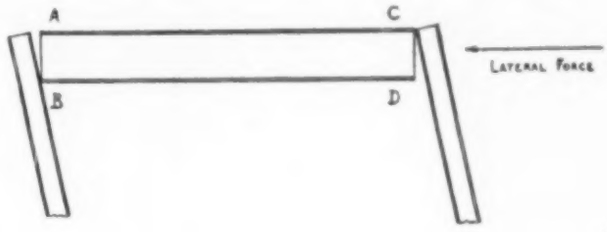


Fig. 2

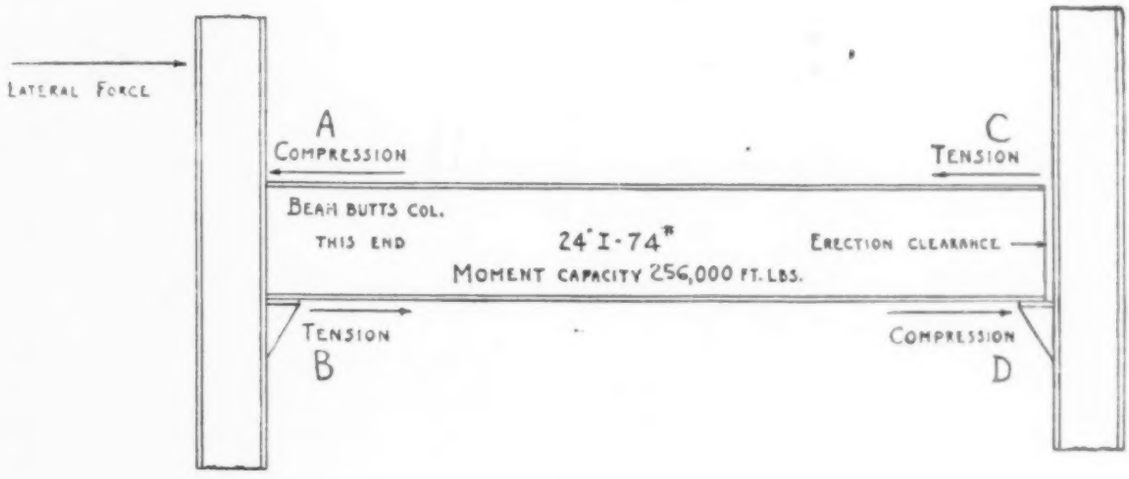


Fig. 3

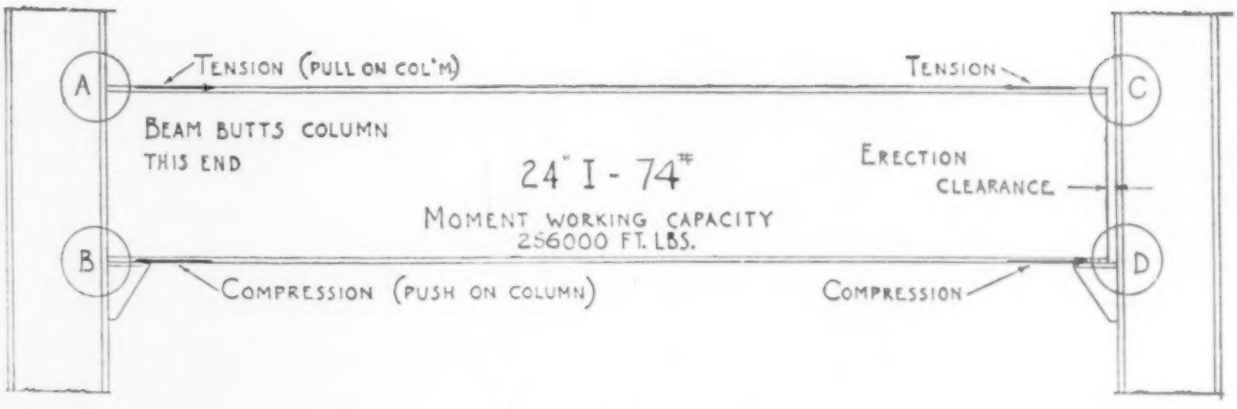


Fig. 4

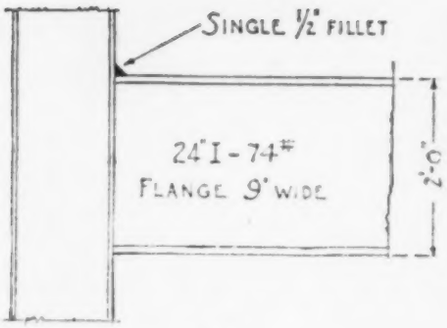


Fig. 5

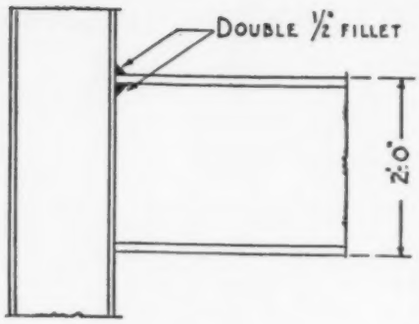


Fig. 6

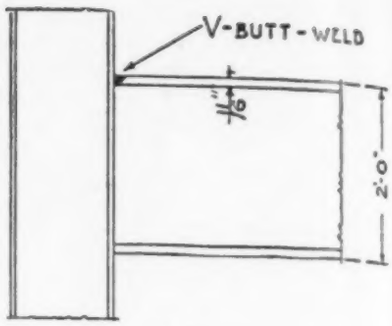


Fig. 7

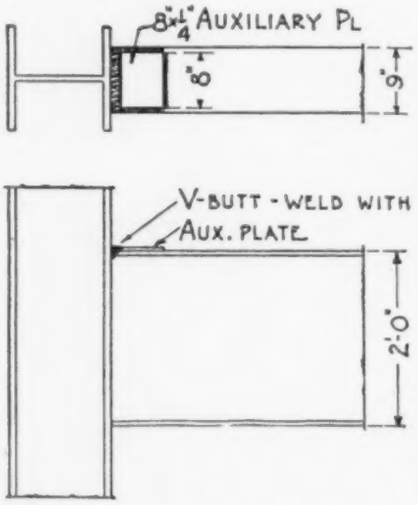


Fig. 8

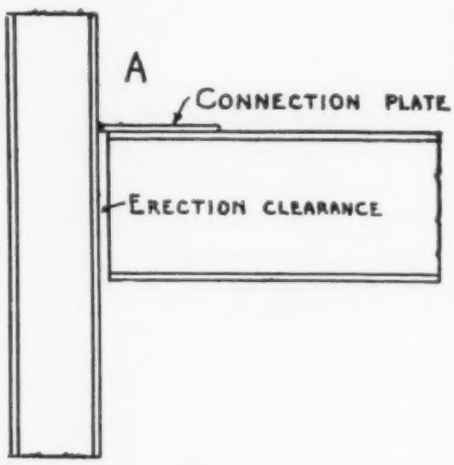


Fig. 9

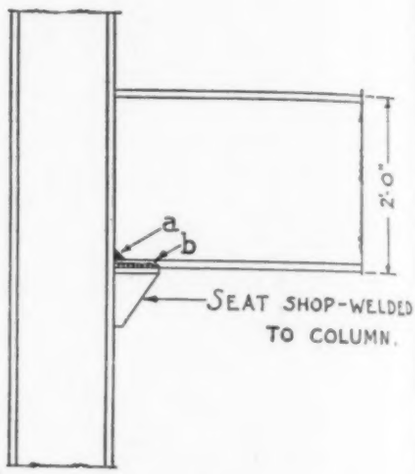


Fig. 10

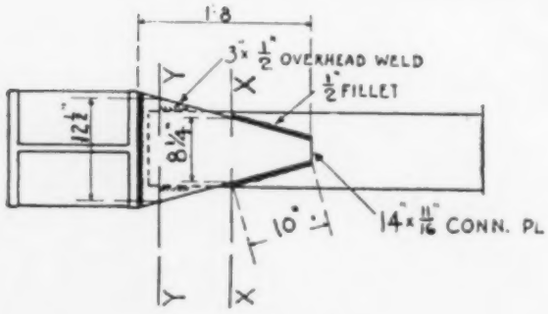


Fig. 11

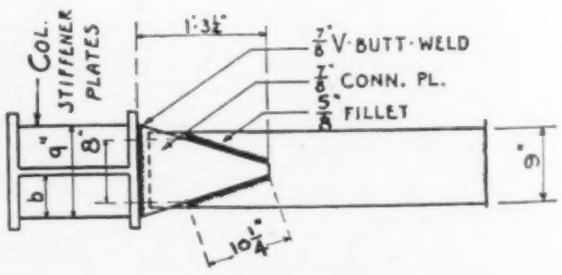


Fig. 12

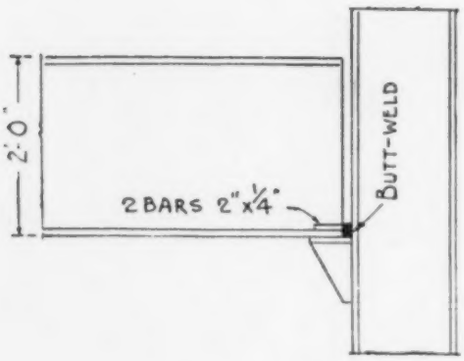
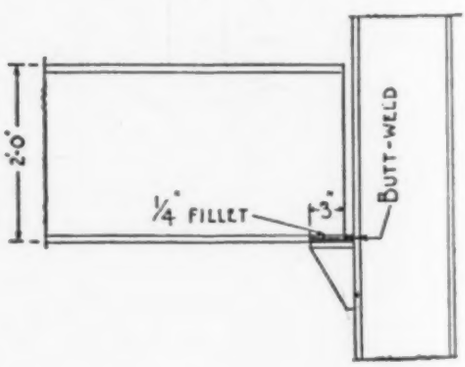


Fig. 13

Fig. 14



were used, the fillet welds connecting the plate to the beam's top flange would transmit 128,000 pounds in compression as well as in tension while the V-butt welds to the column would readily transmit that stress in compression since they are adequate in tension.

It follows from these observations that the strength provided at tension connections for a given requirement is always ample to take care of a reversal to compression.

The converse, however, is not true: the compression connections shown in Fig. 10 and those shown in Figs. 13 and 14 are ample so long as the stress is compression but they are inadequate if the stress reverses to tension as is required at joint *B*, Fig. 3.

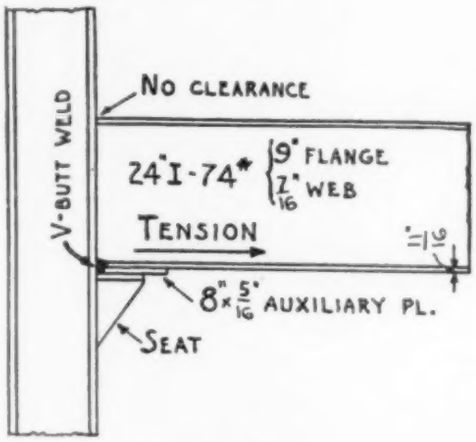


Fig. 15

The simplest tension connection, if the beam is butted to the column face, is that shown in Fig. 15: an auxiliary plate is welded to the beam flange; both beam flange and auxiliary plate are then bevel-cut so as to give the required section for the field V-butt weld. In Fig. 15, deducting the thickness of the web, the beam flange has an area $8\,^{9}/_{16}$ inches × $^{11}/_{16}$ inch = 5.87 square inches; the auxiliary plate has an effective area $7\,^{1}/_{2}$ inches × $^{5}/_{16}$ inch = 2.33 square inches or a total area of 8.2 square inches, which at 16,250 pounds per square inch allowable in tension under the fusion code equals 133,000 pounds. This gives a moment value of 266,000 foot pounds, which exceeds slightly the capacity of the beam.

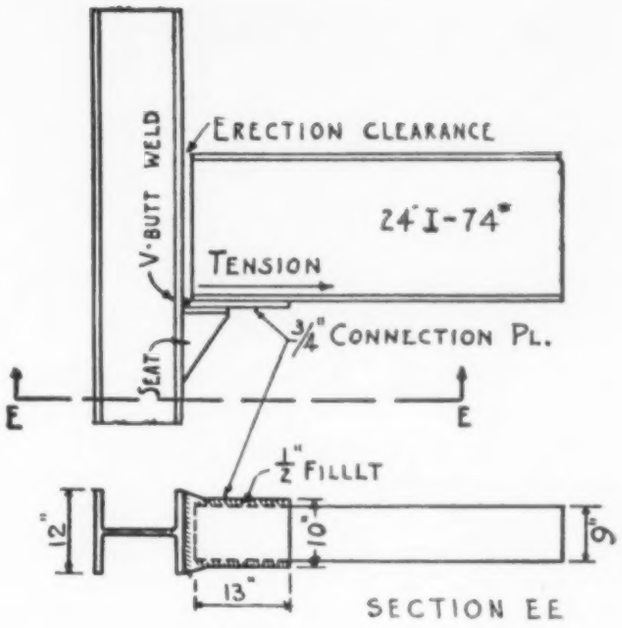


Fig. 16

If there is an erection clearance, a plate is required as shown in Fig. 16. This plate should be wider than the beam flange so as to provide a welding edge along the bottom flange of the beam. In the case shown, the strength of the connection plate is $10\,^{1}/_{2} \times {}^{3}/_{4} \times 18{,}000 = 142{,}000$ pounds. The $^{1}/_{2}$-inch fillet weld's value is $2 \times 13 \times 5000 = 130{,}000$ pounds. The strength of the V-butt weld is $12 \times {}^{3}/_{4} \times 16{,}250 = 146{,}000$ pounds.

In Figs. 15 and 16, the function of the seat is to land the beam when erected and to carry the beam's vertical load.

Frames for Diesel Locomotive Welded

By M. L. Smith*

WITH the adoption of a new design in 1938, the Fate-Root-Heath Company, Plymouth, Ohio, turned to welded construction for the frames of its Plymouth Industrial Diesel Locomotives. Since that time, more than 300 Plymouths with welded frames have been placed in service and not one instance of frame failure has occurred.

While welded frames are used in several models, construction of the frames for the 65-ton Plymouth, which is powered with a 340 horsepower Cooper Bessemer Diesel engine, is typical. These frames consist of two main side members, each $22\,^{1}/_{2}$ ft. by 4 ft. by 4 in., purchased cut to shape. To these side members are welded $1\,^{1}/_{2}$-in. thick top plates, a 6-in. thick front bumper plate, a 4-in. thick rear bumper plate and various internal members. These

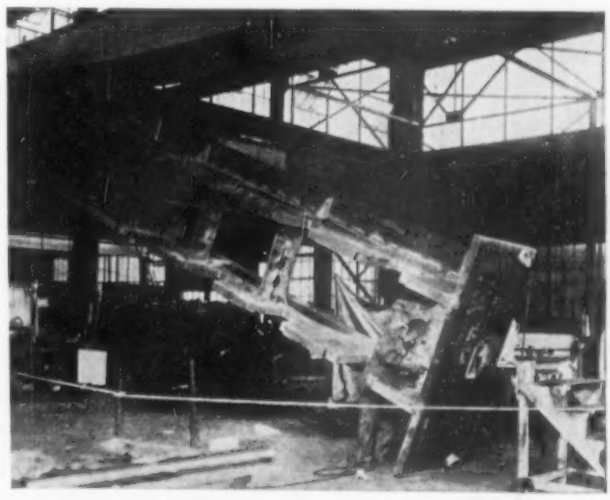


Fig. 1—In Fabricating Frames for Plymouth Locomotives, All Heavy Welds Are Positioned for Downhand Welding

internal members include a built-in oil tank, two 6-in. by 10-in. draw bar pulls at the rear end, also welded to the bumper plate, and four spacers $39\,^{1}/_{4}$ in. long and $1\,^{1}/_{2}$ in.

* Metal & Thermit Corporation, New York City.

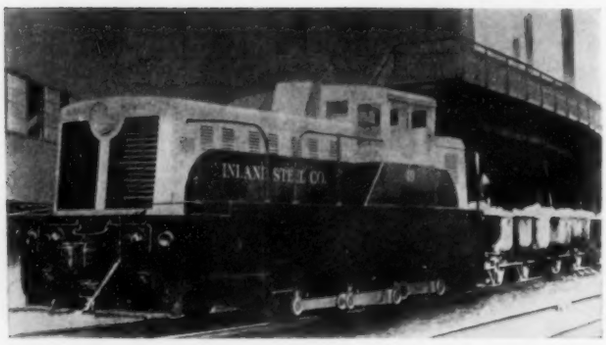


Fig. 2—Sturdy 65-Ton Plymouth Diesel Industrial Locomotive with Welded Frame and Cab

thick which are welded supports for the gear box and planetary transmission.

In assembling the frames, the longitudinal top plates are first welded to the side members. The frame is then turned on its side and spacers are put in plate, followed by the oil tank members and then the bumpers and gear box supports. Each step involves careful lining up and tacking before actual welding is started.

Welding throughout is done with $^1/_4$-in. and $^3/_8$-in. heavy coated electrodes. All corner welds and, wherever possible, all other welds are positioned to obtain the benefits of downhand welding. Gussets between side members and top plates take the shear stresses and permit the use of stitch welding for joining these members. Other welds are all through welds, comprising heavy, multi-pass fillets.

Since aligning tolerance is $\pm^1/_8$ in., considerable care must be taken to avoid warping. The procedure employed comprises back-stepping and welding in short stretches at a number of locations throughout the assembly until an over-all temperature of about 400° F. is reached, after which welding proceeds continuously without further allowance. This method, which provides an even distribution of heat, holds warpage to a minimum and has proved entirely satisfactory.

Welding is also employed in the body of the locomotive. Cab and grill are both of welded construction and the skirts, except for the portions which must be removable for access to the running gear, are welded to the main frame.

All welding is done under the supervision of Mr. D. E. BeBier, Superintendent, and Mr. G. C. Mackey, Welding Supervisor.

Codes and Specifications*

Some New Specifications, and Changes in the Codes

By Russell J. Love†

Introduction

SPECIFICATIONS for metals and codes governing metal fabrication are revised frequently. Developments within the past year have been so rapid that it is felt that the metal-working industry will derive some benefit from these comments on some recent revisions of the rules and standards.

Scope

In general, metals themselves are standardized by means of specifications, whereas the *use* of metals in manufacturing and construction is standardized by means of codes. Most codes contain many references to other specifications, but metals specifications seldom contain explicit instructions for the use of the materials they cover. Some codes, however, masquerade under the designations "standards" or "specifications." Example: The A. P. I. specifications for oil storage tanks and the N. B. F. U. standards for liquefied petroleum gas containers are really construction codes.

The field covered by existing codes and specifications is very broad, and doubt often arises as to the scope of any particular specification or code. Similarly, we occasionally may want to refer to all standards which may be applicable to a particular problem. Figure 1 has been prepared to show the applicability of the specifications under discussion.

SCOPE AND APPLICATIONS \ SPECIFICATION, PUBLICATION, OR CODE:	FEDERAL	A.S.A.	A.S.T.M.	A.I.S.C.	A.S.M.E.	S.A.E.	A.P.I.	A.W.W.A.	N.B.F.U.	A.B.S.	B.M.I.N.	I.C.C.	A.S.M.E.	API-ASME	A.W.S.	A.A.R.
METALS - Properties	X		X		X	X							X			X
- How Made	X		X		X											X
- Heat Trtmt.					X	X										
- Metallurgy					X	X										X
SHAPES - Structural	X			X												
- Automotive						X										
Aircraft	X					X										
TUBULAR GOODS	X	X	X				X	X					X			
FLANGES & FITTINGS	X	X				X		X					X			
NON-PRESSURE CONTAINERS	X						X	X	X			X				
PRESSURE VESSELS									X		X	X	X	X		
WELDING PROCEDURES										X	X		X	X	X	
METALS RESEARCH					X										X	X
STRUCTURES				X			X	X							X	
SHIPS										X	X				X	

Fig. 1—General Scope of National Technical Organizations

Perhaps the most comprehensive set of specifications for metals is that of the American Society for Testing Materials, the well-known A. S. T. M. Part 1 of the A. S. T. M. Standards, covering metals alone, contains over 1300 pages. The most recent complete edition is that of 1939, and the 1940 supplement has nearly 500 pages. In this one year, 1940, we find that 14 new standards were adopted and more than twice that many were revised.

* Presented at Western Metals Congress, American Welding Society, Biltmore Hotel, Los Angeles, Calif., May 19–22, 1941.

† Chief Engineer, Southwest Welding & Mfg. Company, Alhambra, Calif.

New A. S. T. M. Specifications

Significant among the new standards are: A. S. T. M. Specification A-211, which covers spiral welded pipe. This specification establishes acceptable materials for spiral welded pipe, and a uniform rule for calculation of working pressure and hydrostatic test. Specification A. S. T. M. A-83 represents a really up-to-date standard for boiler tubes, whether lap-welded or seamless. Rules for both a flattening test and a flanging test are given, and a companion specification No. A-192, covering seamless boiler tubes for high-pressure service, also is important in this day of high-pressure boilers. Both of the foregoing concern only "ordinary" steel and iron. A new specification for seamless alloy steel boiler tubes covers standardized compositions for chromium-molybdenum alloys, as well as chromium-silicon-molybdenum, and chrome-vanadium and chrome-nickel tubes. All of these alloys are covered now by A. S. T. M. Specification A-213.

It is interesting to note that a standard specification (A-178), was adopted in 1937 for resistance-welded tubes. These tubes, if they met certain requirements, were accepted by the ASME Boiler Code Committee in 1932 for boiler and super-heater service on the same basis as lap-welded tubes but were not standardizedfor this service until 1940, under specification A-226.

Among the non-ferrous metals, we find several new specifications of general interest. Among them are: A comprehensive set of standards for grooved copper trolley wire for industrial hauling (B-116), which is worth noting in view of the present rapid expansion of industrial facilities. Also, in this group we find a new specification of interest to all concerned with automatic controls, namely, B-106, covering the testing of thermostat metals.

Let us glance briefly at the new tentative specifications. Here we find the group of materials which, although they have been in rather common use for some years, have only recently been well enough established as to composition and properties to warrant attempts at standardization. For example, we find that specification A-233–40T sets up a comprehensive classification system for arc-welding electrodes, standards for fillet weld gages and tensile requirements of deposited weld metal. The importance of welding is so great in modern industry that this effort on the part of the A. S. T. M. and the A. W. S. is well warranted and should be received by industry as a whole with considerable interest. Among the new tentative specifications we find also one for carbon steel and carbon-molybdenum steel welding fittings, one for chrome-nickel-steel plate for welded pressure vessels and several for carbon steel and alloy steel forgings. And a process now widely used by the aircraft industry should be aided by tentative specification B-137, prescribing a test for anodic coatings on aluminum. Very interesting is another specification in the non-ferrous group, covering cartridge brass. Specifications for cartridge brass were well established in 1917 and 1918, and revisions were occasionally made up to 1929, when everyone seemed to lose interest in cartridges. Not until 1940 and the inception of the National Defense Program was it found necessary to look into this matter, with the result that we now have a new specification B-19 for the brass that is again important. Similarly, there are new specifications for cartridge case cups (B129), and for bullet jacket cups (B131).

The intent of this brief review is only to call attention to some of these new developments, and those desiring more complete information on the foregoing are respectfully referred to the current A. S. T. M. publications. We will proceed now to a brief survey of new developments in the ways and means of utilizing materials.

Construction Codes

Construction codes, whether for buildings, bridges, pressure vessels or tubular goods, are intended primarily to insure public safety. Accordingly, we find the codes most stringent in those applications of design and construction where the articles produced could cause extensive damage or danger to life, were they not constructed in accordance with strict rules universally enforced. Next to explosives themselves, probably the most hazardous products of the Industrial Revolution were steam boilers. That is, they were hazardous until the A. S. M. E. power boiler code came into general use. Only slightly less hazardous, if carelessly built, would be unfired pressure vessels and bridges and buildings.

By referring again to Fig. 1, you will note how many pressure vessel codes there are. It might be stated, however, that several of these are of limited application. For example, the Bureau of Marine Inspection and Navigation (B. M. I. N.) is concerned only with pressure vessels used on shipboard. The National Board of Fire Underwriters is interested principally in inflammables, and the I. C. C., the Interstate Commerce Commission, although interested in containers for commodities of all sorts, prescribes rules for such containers only where involved in the Interstate transportation of those commodities. The A. P. I.-A. S. M. E. Code, first published in 1934, is intended only for unfired pressure vessels for petroleum liquids or gases. It might be well to point out that the B. M. I. N. and N. B. F. U. Codes refer almost directly to the A. S. M. E. Code for the basic rules of pressure vessel fabrication. It is to be hoped that the I. C. C., whose rules now take little cognizance of the other pressure vessel codes, will eventually do likewise. The early combination of the A. S. M. E. and A. P. I.-A. S. M. E. Codes, on which committees are now working, may serve to unify all organizations concerned with pressure vessel fabrication.

Code Revisions

Both the A. S. M. E. Power Boiler Code and the Unfired Pressure Vessel Code, in their 1940 editions, have been brought thoroughly up to date. Significant among the recent revisions in these codes is the recognition of the suitability for pressure vessel construction of many newly developed materials. To illustrate the progress made in the three years between 1937 (the date of the last previous edition) and 1940, the current edition, in 1937 the A. S. M. E. Code listed only about 40 materials as suitable for all applications within the scope of the code. In 1940, more than 60 acceptable materials are specified. The newer materials roughly correspond with the materials discussed in the first part of this paper Significantly, the alloy steels are now generally recognized, and, in addition, the use of non-ferrous materials is facilitated by a much more comprehensive treatment of the allowable stresses therein, than formerly.

A good example of the generous recognition of recent progress both in materials and methods is afforded by the 1940 revision to the A. P. I.-A. S. M. E. Code, viz.:

1. Carbon-Moly steels for high-temperature service are now permissible. The use of these steels has been permissible under the A. S. M. E. Code for some time, and in some cases higher stresses were permitted under

the A. S. M. E. Code than under the A. P. I.-A. S. M. E. This is no longer the case.

2. Electric resistance welded pipe is now permitted for use as nozzle or manway necks, or even for shells. Joint efficiency allowed is 85%.

3. Inspection opening requirements are now more strict. All vessels larger than 36 in. diameter must have at least one manway.

4. The rules for bolted flanged connections have not been mandatory in so far as design of bolting flanges was concerned. The Code revision now states that none of the rules under Paragraph W317 are mandatory. This means that other methods of flange attachment may be used. This enables designs like those required for quick-opening covers to be functionally designed.

5. Alloy steel bolts were formerly limited to 15,000 psi working stress at ordinary temperatures, although their ultimate strength was 125,000 psi. The Code revision permits higher stresses for alloy bolts, up to 25,000 psi.

6. Joint efficiencies formerly attainable only with double-welded butt joints are now allowable for welding processes "providing proper fusion and complete penetration and avoiding the presence of defects at the base of the weld." This means that one pass automatic welding may be used without back chipping or back welding, provided that it can be demonstrated that the metal at the root is of satisfactory quality. Test requirements, of course, must meet the requirements for double-welded butt joints.

7. The roundness tolerance for shell sections remains a maximum of 1% (difference between max. and min. diameter at any cross section), *except* that at cross sections through shell connections such as manways or nozzles, an additional tolerance is allowed which permits some distortion due to the welding of the attachments to remain uncorrected.

8. All vessels requiring 100% X-ray examination must have welds to be X-rayed ground or chipped smooth, to eliminate surface irregularities from showing on the film. The old style thickness gages or penetrameters formerly used when X-raying "unfinished" welds are now obsolete.

The A. S. M. E. Code is continually considering, by committees, requests for Code interpretation, and pleas for revisions and modifications. The Code committees' interpretation of these requests, most of which eventually become code revisions, are conveniently available in the magazine, *Mechanical Engineering*, or by subscription to the "Code Interpretations." Glancing through some of the recent interpretations we find the following new developments:

1. Chrome-nickel (stainless) steels, with or without columbium, titanium or molybdenum, may be used for unfired pressure vessels, subject to proper heat treatment when required.

2. The provision that a backup strip is required to make a single V weld equivalent to a double-welded joint may be waived if proper fusion and penetration are obtainable by the single welding process. (This ruling is substantially the same as the A. P. I.-A. S. M. E. change No. 6, above.)

3. Stays for jacketed unfired pressure vessels may be plug- or slot-welded instead of threaded or riveted, provided the pressure is not over 150 psi and the plates are not over $\frac{1}{2}$ in. thick, plus certain detailed welding restrictions (see Case No. 883). (This construction was not allowed prior to 1939, then was limited to 25 psi working pressure until 1940.)

4. Tubes may be attached to drums of water-tube boilers by welding without expanding or flaring, subject to observance of welding rules per Paragraphs P-101 to 110, P-212 and P-268.

5. Unstress-relieved vessels having nozzles larger than 10% of the shell diameter formerly required those nozzles to be locally stress-relieved. It is now realized that more harm than good may be caused by attempts at localized stress relief. Large nozzles are now not required to be stress-relieved unless the vessel as a whole is stress-relieved.

The development of welding processes is recognized by the Codes, by revised rules for qualification of both the welding process and the welding operator. At the same time, these rules are formulated in such a manner that continued progress in the development of welding methods is unhampered.

The parallel growth and development of both specifications and construction standards is also well illustrated by the fact that the American Standards Association in 1939 issued new standards for steel flanges and flanged fittings. These, of course, are very necessary accessories for all types of pressure vessels. Reference to the A. S. A. Standards, where applicable, is now made by all pressure vessel codes and of course the power piping code, which is sponsored by the A. S. A.

The American Institute of Steel Construction (A. I. S. C.) rules have long governed safe structural steel design. Now, through the joint efforts of the American Society of Civil Engineers, the A. I. S. C. and the AMERICAN WELDING SOCIETY, structural steel fabrication is rapidly being modernized to permit application of newer methods of fabrication. And through the concerted efforts of these national organizations, local ordinances are gradually being revised to permit new construction methods as they become standardized.

Conclusion

An attempt has been made to call attention to the nature of recent changes in Codes and Specifications. Doubtless many are already familiar with the items covered, but there are probably others who have been unable to become thoroughly acquainted with the many specific changes that have occurred within the past year. It is hoped that this presentation, although by no means giving a complete coverage of the field, has enlightened some, and reminded others, that our national technical organizations are keeping abreast of the times, and it is up to us as individuals to keep abreast of new data just as rapidly as it becomes available to us.

Structural Welding

By A. F. Davis*

Welded Building Shows Feasibility of Steel Fabrication at Job Site

Fig. 1—Architects' Drawing of the Lincoln Electric Co. Building at Leaside, Ontario

A NEW facility in building construction which permits unprecedented simplicity and speed in steel erection and which has particular application under the present system of war priorities, was noted in the recent completion of a new industrial plant for the Canadian Lincoln Electric Company, subsidiary of The Lincoln Electric Company, manufacturers of arc-welding equipment, Cleveland, Ohio. The location of the new building (see Fig. 1) is at Leaside, Ontario.

This new facility is the fabrication of structural steel at the job site. In the particular instance of the new Lincoln building, job-site steel fabrication eliminated delays induced by priority war orders. Although the original intention was to fabricate all the steel in the shop, the development of unforeseen delays made it necessary to move all the steel to the job and complete the fabrication there.

* Vice-President, The Lincoln Electric Company, Cleveland, Ohio.

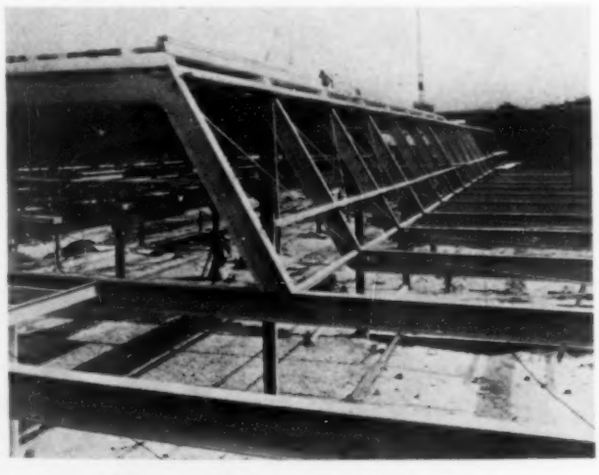


Fig. 2—Framing at Inclined Portion of Roof

Interesting details of this project are shown in the accompanying illustrations.

In fabricating the column-to-purlin connection, it was first necessary to cut the lower flange of the purlin away and curve it to the proper radius. The next step was to cut the filler plate to shape and place it on the lower part of the purlin web. Completion of the connection consisted of welding the filler plate to the web of the purlin, also to the bent-down lower flange. A view of this connection joining a purlin to a column is shown in Fig. 3.

Other examples of facilities provided in steel erection by use of welding are the various clip angle seats, split I-beam segments, tie-rod clips, etc., which can be seen in Figs. 4 to 9, inclusive.

Fig. 3—Junction of Roof Purlin and Column

The building has exterior dimensions of 302 feet by 100 feet. The general offices are located in a space 40 feet wide extending the full width of the building across the front. There are 8 bays of monitor-type roof with end bays of flat roof construction. A maximum of interior light is admitted by utilizing as many windows as possible in all walls and by installation of continuous glazed sash on the inclined portions of the raised roof.

Four rows of H-columns, spaced 32 feet 10 inches apart, with the columns themselves on 30-foot centers, carry the steel frame of the building. Columns in the exterior wall are 8 inches by 8 inches while the inner rows are 12 inches by 8 inches to take care of the increased length of column and the additional load of the roof frame. The exterior columns carry 18-inch, wide-flange beams as wall girders. Longitudinal girders, carried by the interior columns, are 24 inches in depth.

The roof purlins, previously discussed, are continuous from wall to wall over the raised part of the roof, being bent up to form the monitor. Two interior girders carry the straight central part which is cantilevered out 8 feet. The structural steel in the building amounts to approximately 125 tons.

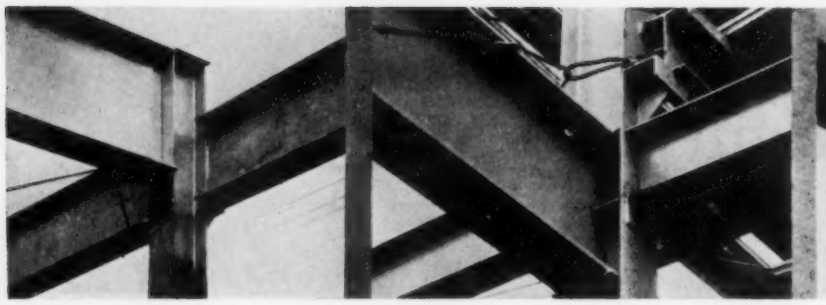


Fig. 4—Junction of Roof Beam and Eaves Strut at Front

Fig. 5—Typical Connection of Girder and Beam to Column

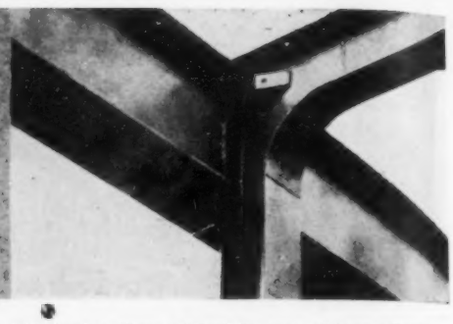


Fig. 6—Junction of Roof Beam and Eaves Strut at Rear

A very attractive interior is provided by the welded steel work including the curves at the connections, the unbroken surfaces of the steel and the absence of many cross braces which would be necessary with conventional construction. Further advantages include a very definite saving in steel, better surfaces for painting and greater freedom from troubles due to rust.

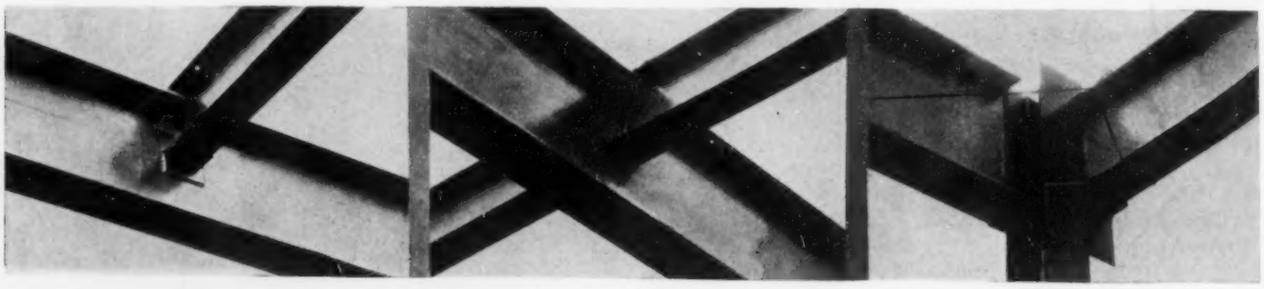
The new building was designed by C. D. Carruthers and staff. Architects were Mathers and Haldenby with Gordon L. Wallace serving as consulting structural engineer. W. B. Sullivan was the general contractor and John T. Hepburn, Ltd., did the steel fabricating and erecting.

Due to its possibilities, this new structural facility may be of great importance in military engineering. Because of the need for fast construction of temporary bridges and buildings of many types, cutting and welding equipment may become important items in the tool kit of the military engineer.

Fig. 7—Junction of Roof Beam and Girder

Fig. 8—Junction of Lower Roof Beam at Girder

Fig. 9—Intersection of Lower Roof Beam and Girder



Unique Design in Welded Steel Features New Cleveland Church

A NEW church, first in which a Gothic effect (see Fig. 10) is achieved in an all-welded steel-framed building and the only free-standing structure in existence with such tremendous roof pitch, is being completed at Cleveland, Ohio, according to the designers.

This church, the Fairmount Presbyterian, of which Rev. Frank Halliday Ferris is pastor, is 150 feet long, 55 feet wide and 50 feet high, costing approximately $250,000.

The framework is entirely welded and, according to the structural engineer, welded construction is the only method by which the structure is feasible.

The tremendous pitch of the gable frame roof (see Fig. 11) and the fact that the entire structure is free-standing makes it unique. The pitch of roof is exactly 45 degrees, more than twice that (20 degrees) of average roofs. There is no lateral bracing whatever.

This unprecedented pitch, plus wind and slate loads, necessitated greatest possible rigidity and gave rise to the unique feature of the design—the use of bent channels and plate arc welded to form the haunch section of columns.

Fabrication of a haunch consisted of cutting a vee into each channel, bending to desired contour, placing

Fig. 10—Architect's Rendering of New Fairmount Presbyterian Church of Cleveland, First Ever Constructed in Which a Gothic Effect is Achieved by All-Welded Steel Framing

the two bent channels together with a cut plate in a special jig, the plate touching each channel at center line of web, then fillet welding at each side of the plate.

Columns and roof frames being I-beams (18-inch x 70 pound), the haunch section web plate was butt welded to webs of columns and beams while the haunch channel flanges abutted the I-beam flanges in a V-shaped joint (see Fig. 12).

Fig. 11—All-Welded Steel Frame of New Cleveland Church, First Ever Built in Which Channels Comprise the Principal Load-Carrying Members in Column Haunches

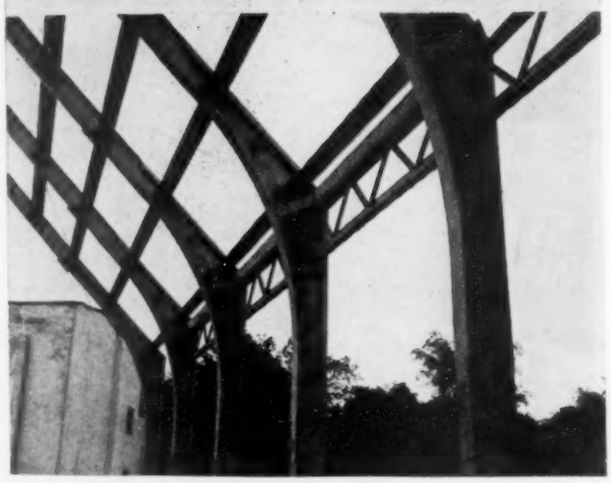


Fig. 12—View of Frame at Junction of Columns and Roof Beams Showing Haunch Sections Fabricated of Bent Channels and Plate Arc Welded

Column, haunch and roof frame, comprising one-half a frame bent, constituted one fabricated unit. They are trucked to the site.

In erection, the two halves of a bent were placed, held in position until the other was erected, then both were allowed to assume positions, butting together at the peak. It is interesting to note that all steel was placed in less than two days, with the observation by the erector that one day would be more than ample for a second job of the same type.

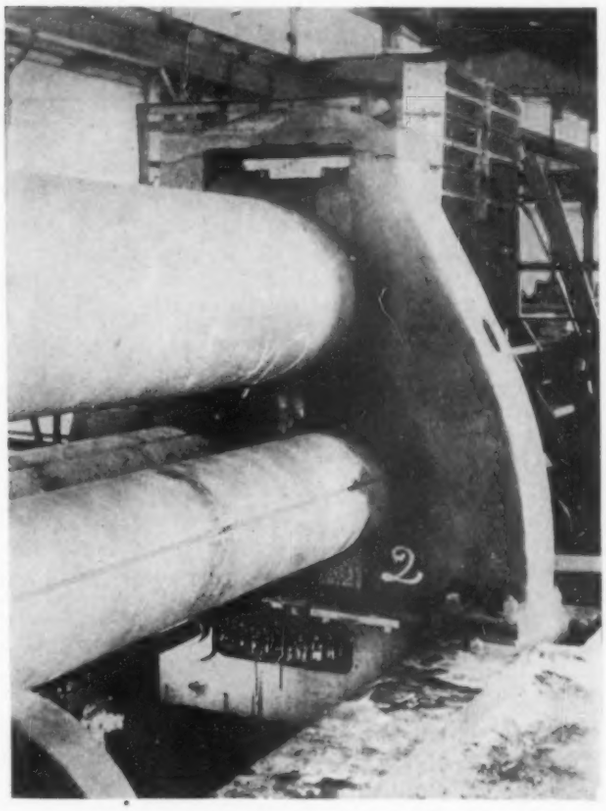
Design was by Walker and Weeks, structural welding engineering by C. Merrill Barber, steel fabrication by the Austin Co. and erection by Vogt and Conant, all of Cleveland. All welding was by the shielded arc process.

Providing as it does the most efficient possible use of steel and a degree of rigidity which the structural engineer claims could not be matched by any other design, this new development is expected to find wide usage in all types of free-standing structures.

Casting for Shipyard Plate Roller Replaced by Arc-Welded Construction

WHEN the casting broke supporting the lifting mechanism and top roller weighing 40 tons on a huge 30-foot-long plate roller at the Ingalls Shipyard in Pascagoula, Mississippi, maintenance men decided to replace the casting with a casting of arc-welded steel construction. The broken cast-iron casting had been manufactured by the now defunct Hilles & Jones Company of Wilmington, Delaware. A new cast-iron casting could not be obtained for several months, so in order to alleviate the long shut-down an all-welded casting was constructed from $1^1/_4$-inch steel plate.

The new arc-welded casting was constructed in five days at only a fraction of the huge expense from shut-down that waiting for an iron casting would have necessitated. Ernest L. Curry, maintenance machinist at Ingalls, who reported this job in the Hobart Arc Welding News Contest says, "The new welded casting is much stronger than the old one with more torque strain and flexibility." And once again the versatility of arc-welded construction has kept the vital machinery of defense industry moving along at its speeded pace.



Photograph courtesy Hobart Brothers Company

Welding Society

ACTIVITIES — Related Events

EDUCATIONAL MEETING

There will be scheduled as a regular part of the Annual Convention of the AMERICAN WELDING SOCIETY, on Monday evening, October 20th, a meeting of the Educational Committee. This is to be an open meeting and it is urgently requested that all members of the SOCIETY in any way interested in the educational phases of welding attend.

While considerable stress has been placed on the importance of welding in engineering curricula in general, it is the opinion of many that the process and its ramifications have not yet received proper emphasis in engineering educational institutions. Ways and means for the effective dissemination of welding information will be discussed, and all members of the SOCIETY are invited to present suggestions before the meeting.

It has been proposed that the Report of the Committee on Minimum Requirements of Instructions for Welding Operators in Trade Schools also be discussed at this time.

THE PRESIDENT'S MESSAGE

In the daily press, trade and technical periodicals there are to be found many discussions of three elements of production, namely, materials, equipment and labor. The available supply of each, possible substitutes and problems of increased production have been given careful attention. These studies have included the redistribution and pooling of resources, the increase in facilities for obtaining greater capacity of production of equipment and materials, and plans and facilities for the training of labor. There is a fourth essential to which little discussion has been devoted and insufficient thought given. This fourth essential is technical knowledge.

Notwithstanding the comparative ease of dissemination there is a considerable difference in the level of technical knowledge from industry to industry and from one industrial unit to another. As long as there are differences in the natural ability of men, differences in policy of industrial units and differences in financial ability to maintain technical services there must result, as a consequence, considerable variations in technical standards and practices.

Variations in the level of technical knowledge can be best broken down by increased freedom of publication and conference. There is a tendency to discourage this leveling-out process because of pressure of work on technical personnel and particularly because of the feeling that information essential to National Defense will be disseminated. The possibilities of increased quantity and quality of production and of the elimination of waste through ignorance far outweigh the harm which we would experience through the disclosure of technical knowledge, beneficial to those we would exclude from our family of technicians. Far greater gains will come from elimination of waste effort because of duplication of work and from the stimulation of thought and invention that comes from the exchange of ideas.

Our demand for materials and equipment has necessitated not only the full use of available production facilities but has required an expansion of those facilities. There are many evidences that our facilities for producing technical knowledge are not being fully utilized, much less expanded. If this observation is true, it represents a condition which should not be tolerated in a nation advertising itself as an arsenal for freedom loving people.

METAL CONGRESS

With its service to the industry emphasized by the demands of the national defense program, the National Metal Congress and Exposition, to be held in Philadelphia, will be more pretentious this year then ever before, advance sales of exhibit space for the Congress indicate.

Space sales for the 1941 five-day meeting, opening October 20th in Philadelphia's Commercial Museum and Convention Hall, are 10 per cent ahead of last year, according to W. H. Eisenman, director of the Metal Congress and secretary of the American Society for Metals, which sponsors the show.

"In these purchases of exhibition space," said Mr. Eisenman, "we see the evidence of a sound advertising policy on the part of metal men and those of associated industries.

"In other words, the temporary prosperity of the defense program has not blinded these men to the need of continued effort in building goodwill against the time when there are no more armament orders, and the companies that have been devoting most of their production to the defense work must once more compete in the open market for business.

"This tendency toward a more liberal advertising policy is not confined to exhibit space only. It has been noted in recent months that metal men are buying more trade journal and newspaper space as media for keeping their names and products before their trade public."

The importance of metals to the national defense program will be the general theme of the Congress, and it is understood many of the exhibitors will feature at the show products and new methods which they are using to assist American defense production.

The Congress is held in conjunction with the annual meetings of the American Society for Metals, THE AMERICAN WELDING SOCIETY, The Wire Association and the Institute of Metals division and the Iron and Steel division of the American Institute of Mining and Metallurgical Engineers.

Technical sessions of the various groups will be held in downtown Philadelphia hotels during the five-day sessions of the Congress.

ANNOUNCEMENTS OF NEW A. S. T. M. OFFICERS 1941–42

Nominations for officers of the American Society for Testing Materials, for 1941–42 are announced. Official notice of election will be given at the First Session on June 24th, of the Forty-fourth A. S. T. M. Annual Meeting in Chicago, Ill.

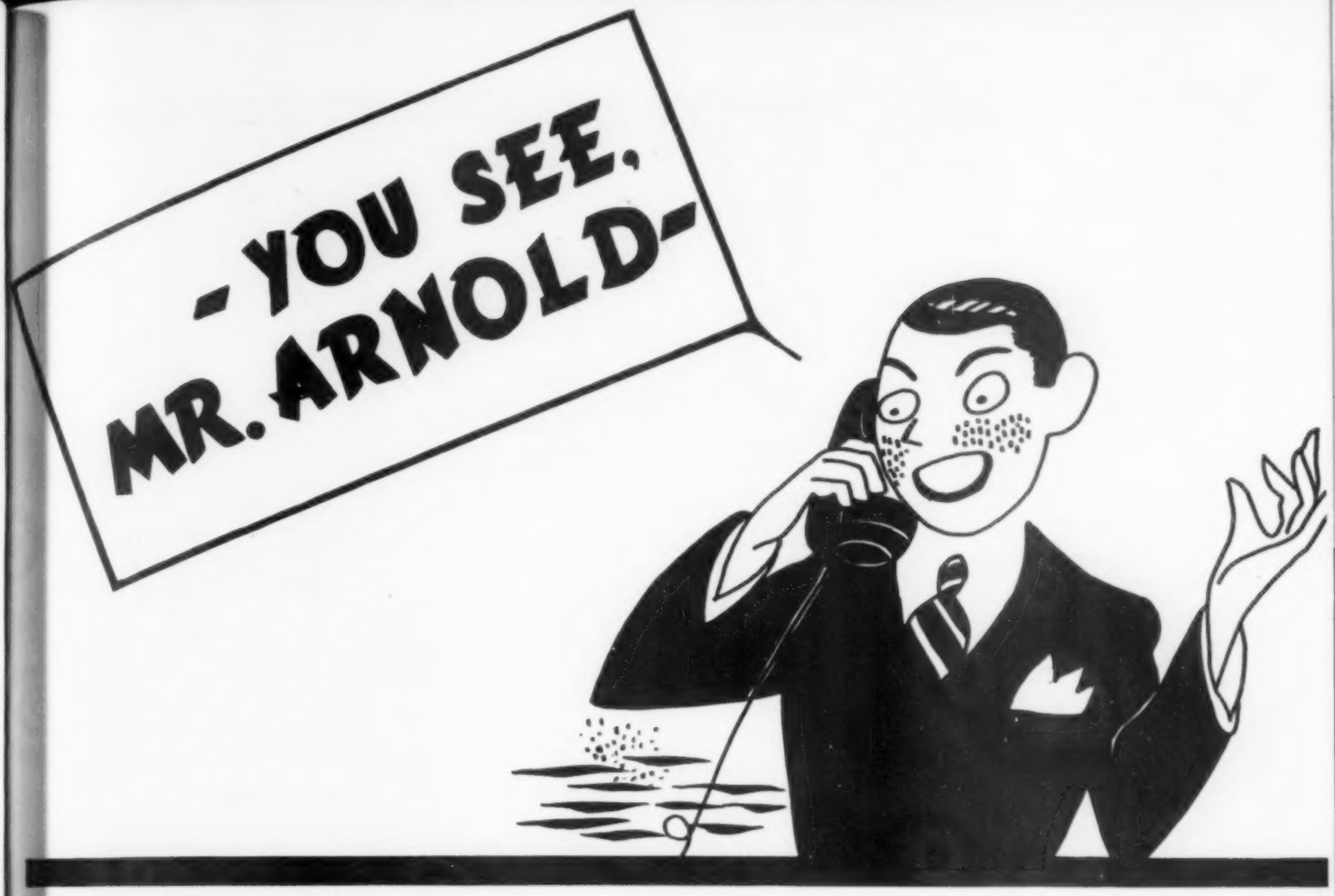
President (term, one year): G. E. F. Lundell, Chief, Chemistry Division, National Bureau of Standards, Washington, D. C.

Vice-President (term, two years): Dean Harvey, Materials Engineer, Engineering Laboratories and Standards Dept., Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

Members of Executive Committee (term, two years): Arthur W. Carpenter, Manager, Testing Laboratories, The B. F. Goodrich Co., Akron, Ohio; T. A. Fitch, Director, Bureau of Standards, City of Los Angeles, Calif.; Carl D. Hocker, Plant Products Engineer, Bell Telephone Laboratories, New York City; J. L. Miner, Director and Vice-President, Atlas Lumnite Cement Co., New York City; E. W. Upham, Chief Metallurgist, Engineering Dept., Chrysler Corp., Detroit, Mich.

TRAINING COURSE

More than four hundred men have been trained for welding jobs in the Aircraft and Shipbuilding Industry by the Welders Training Course conducted by the College of Engineering at the University of Oklahoma. Wm. T. Tiffin is director of the



Nothing irritates a customer more than being told he can't have a product when he wants it. And nothing is more embarrassing to a salesman—and his company—than to have to give alibies for delayed deliveries.

Much as it is the earnest desire of electrode manufacturers to maintain normal delivery schedules, in these uncertain days there are too many factors beyond their control for them to do so in all cases. The continuous step-up in the demand for electrodes, the priorities situation, and the restrictions on certain metals are just a few of the difficulties with which the electrode manufacturer must contend under today's conditions.

By ordering electrodes when you order steel you can minimize the chances of production delay due to electrode shortages. Your requirements are generally known at that time and by anticipating your demands electrode manufacturers can serve you better.

In the meantime, the cooperation of our engineering staff is at your disposal—for helping you speed up welding production or working out a new welding procedure if you are not satisfied with present results.

METAL & THERMIT CORPORATION • 120 BROADWAY, NEW YORK

ALBANY • CHICAGO • PITTSBURGH • SO. SAN FRANCISCO • TORONTO

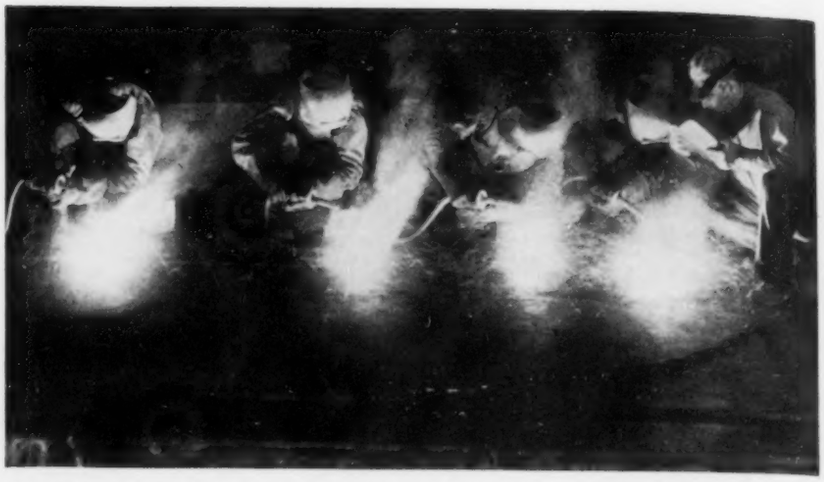
MUREX HEAVY COATED ELECTRODES

THERMIT WELDING — STANDARD FOR 40 YEARS FOR WELDING RAILS AND HEAVY EQUIPMENT

course with L. E. Dietrich as chief instructor assisted by Pat Walters.

Twenty-four students are now enrolled, eighteen taking instruction in shipyard welding, three specializing in aircraft welding and three specializing in aluminum and stainless steel welding as required in the laboratory for construction of instruments and research equipment.

Anticipating extension of the course, gas and electric heat-treating furnaces are being installed while additions to the laboratory include a research type metallascope, a metallurgical microscope, analytical equipment and photographic equipment for micro and macro photography.



Elder Rice, Training Instructor, Supervises a Class of Four Apprentice Welders at the Ambridge, Pa., plant of the American Bridge Company, United States Steel Corporation Subsidiary.

DEFENSE TRAINING

To meet pressing defense requirements, 15,000 employees of United States Steel subsidiaries are now undergoing intensive training for skilled jobs.

The fact that a training program has long been in effect made it possible for the steel manufacturing subsidiaries of the Corporation to increase their output in a little more than six months' time from two-thirds of capacity to full capacity, which over a 12-month period would produce steel in excess of the entire annual steel output of Germany, based on the latest available figures.

The need for skilled men, not only for the production of steel but also for the manufacture of defense items such as cruisers, destroyers, merchant vessels, armor plate, shell forgings and bomb castings, now being made by United States Steel, is growing each day and many of the trainees are receiving their instructions on the job. Others are given preliminary training before being put on production work.

In regular operations there is commonly a natural progression upward from one job to another, depending, of course, on the aptitude, acquired skill and general qualifications of each individual employee.

Through this method, known as "upgrading," it is possible to expand from one shift to three or more shifts, using the original personnel as a nucleus.

In training men for special defense work, such as the manufacture of armor plate, bombs and shells, it has been necessary to give large numbers of men intensive instruction in the operation of single-purpose machines.

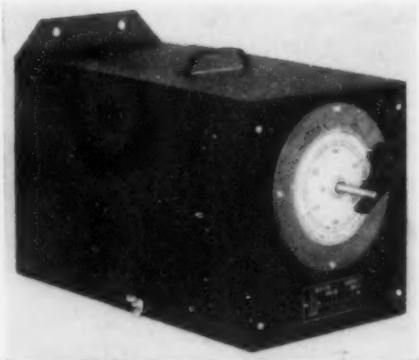
As a preliminary to learning these operations, many of the men are given training in machine operations in the public schools or in the company machine shops. This kind of training, as well as the upgrading of men in regular mill operations,

FINGER TIP REGULATION OF SPOT WELD TRANSFORMER HEAT—
AND POSITIVE UNIFORMITY IN YOUR WELD TIME—

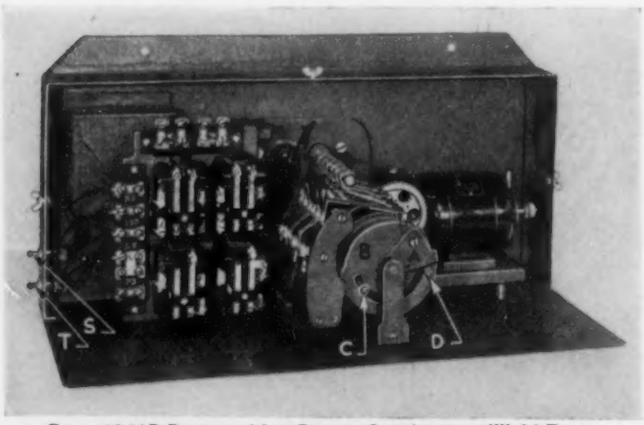
DON'T OVERLOOK THIS NATIONAL SET-UP

National Weld-Timers are Simple, Reliable, and Surprisingly Low in Cost.

The Model 41 Phase Shifting Heat Control Provides the Equivalent of MORE than 60 Transformer Taps, Instantly Selected, by Turning the Pointer Arm.

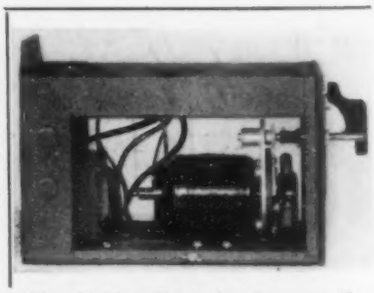


The movable brushes regulate the firing point of contactor, with respect to the zero point of the voltage wave. These can be moved around so near zero that weld current ceases to flow.



Type 1860P Repeat—Non-Repeat Synchronous Weld Timer

Synchronous motor driven Heat Control rotates a copper segment between 2 opposing brushes, to close the Ignitor circuit of a tube contactor, every half cycle.

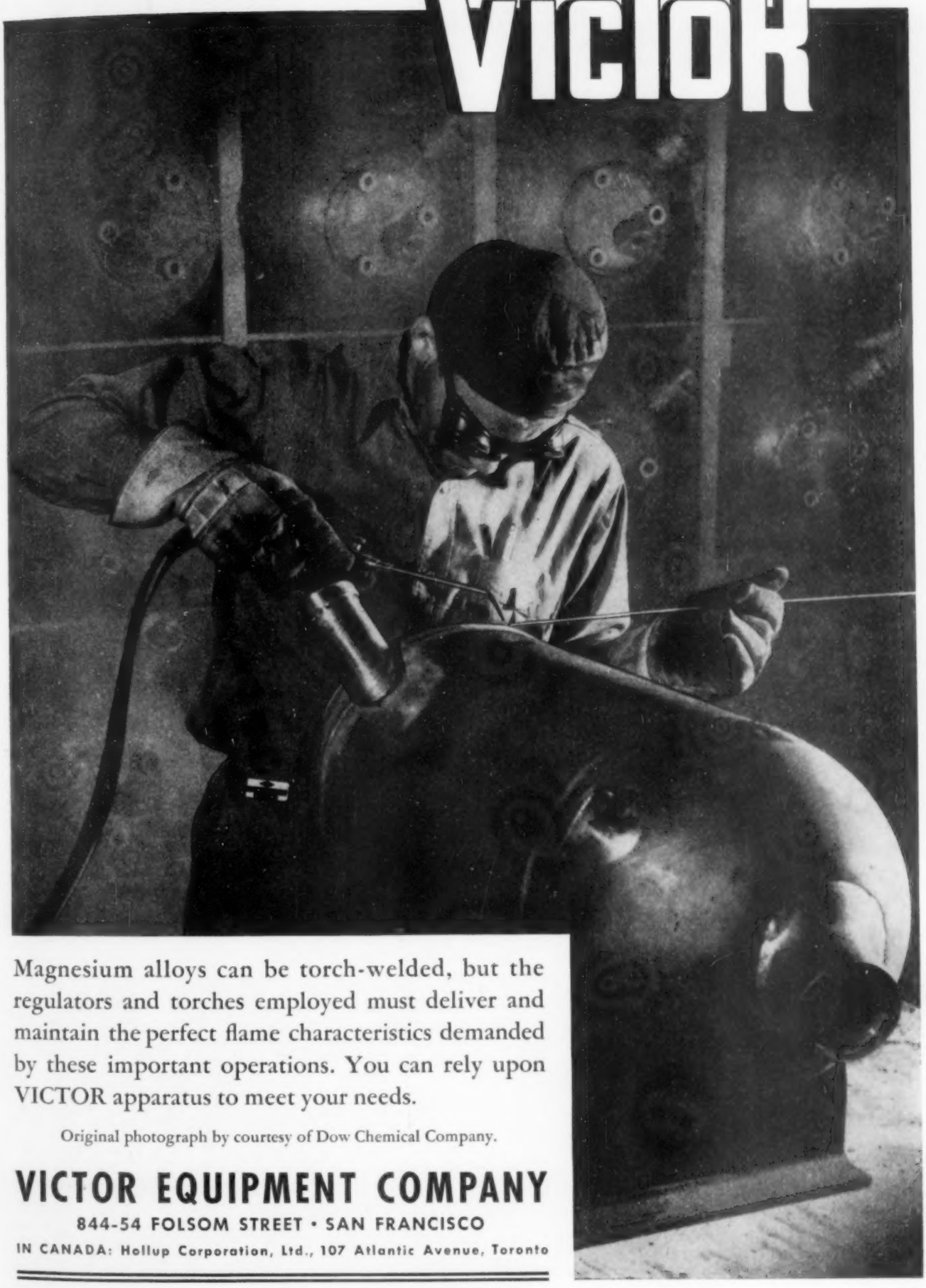


No. 41 Heat Control with cover off.

NATIONAL TIME & SIGNAL CORPORATION

600 E. MILWAUKEE AVENUE DETROIT, MICHIGAN

VICTOR



Magnesium alloys can be torch-welded, but the regulators and torches employed must deliver and maintain the perfect flame characteristics demanded by these important operations. You can rely upon VICTOR apparatus to meet your needs.

Original photograph by courtesy of Dow Chemical Company.

VICTOR EQUIPMENT COMPANY

844-54 FOLSOM STREET • SAN FRANCISCO

IN CANADA: Hollup Corporation, Ltd., 107 Atlantic Avenue, Toronto

is separate from the subsidiaries' long-range apprenticeship program where more than 1300 apprentices are now taking four-year courses in steelmaking in steel-fabricating units of United States Steel Corporation.

INSTRUCTORS NEEDED FOR ARMY AIR CORPS TECHNICAL SCHOOLS

The Army Air Corps needs instructors for their Air Corps Technical Schools at Chanute Field, Rantoul, Illinois; Scott Field, Belleville, Illinois; Biloxi, Mississippi; and Wichita Falls, Texas. The Civil Service Commission has announced a nation-wide examination to secure persons for these jobs. An insufficient number of qualified persons were obtained through previous examinations held for these positions. Persons who can meet the requirements are urged to file their applications *at once*. No written examination is required. Applications may be filed until further public notice.

There are three grades of positions—Assistant Instructor, $2600; Junior Instructor, $2000; and Student Instructor, $1620. Opportunities for advancement are excellent. Within thirty days after appointment persons may be promoted to a higher grade, up to a maximum of $3800 a year. For the Assistant and Junior Instructor grades, persons may qualify in the following optional branches: Aircraft Carburetion Systems, Aircraft Engines, Aircraft Hydraulic Systems, Aircraft Instruments, Aircraft Mechanics, Aircraft Propellers, Aircraft Electric Systems, Aircraft Sheet Metal Work, Aircraft Welding, Machinist, Parachutes, Vocational Training, Radio Operating, and Radio Engineering. Assistant and Junior Instructors will teach officers and enlisted men of the Army in the optional subjects indicated.

Applicants for the Assistant and Junior Instructor grades must show that they have completed at least 14 units of high-school study. Except for certain substitution of college study, applicants must have had at least 4 years of training or experience which gave them both a practical and theoretical knowledge of the particular option in which they are making application, which must have included at least 6 months of instructional or supervisory experience in the particular option. In lieu of this experience, a bachelor's degree in aeronautical engineering from a recognized private or vocational school will be accepted; or for each year of the experience lacking, appropriate college study may be used.

NAVAL ARCHITECTS AND MARINE ENGINEERS STILL SOUGHT FOR GOVERNMENT SERVICE

Revised examinations have just been announced by the Civil Service Commission for persons qualified in all branches of Naval Architecture and Marine Engineering. Persons are particularly needed for filling positions in the Assistant and Associate grades ($2600 and $3200 a year, respectively). However, Naval Architects or Marine Engineers qualified to fill all the grades (salaries range as high as $5600 a year) are urged to apply at once although applications will be accepted until June 30, 1942.

Every effort is being made by the Commission to secure well-qualified persons to meet the need of the national defense program for marine engineers and naval architects. Persons who are interested and qualified should file their applications with the Commission's Washington Office. Further information including the exact experience, education and substitution provisions may be secured at any first- or second-class post office or from the Civil Service Commission.

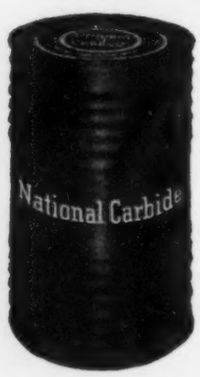
DEPARTMENT OF COMMERCE, WASHINGTON

Approximately 2500 government purchasing agencies purchase some 300,000 different articles. Indeed, the government buys some quantities of almost everything produced in this country.

The magnitude of the government purchasing set-up, especially in this grave emergency when first emphasis is necessarily placed upon defense equipment for the expanding Army and Navy and for Great Britain, tends to confuse many manufacturers who desire to cooperate 100 per cent.

Actually, government purchases are

National
Carbide



DEPENDABLE

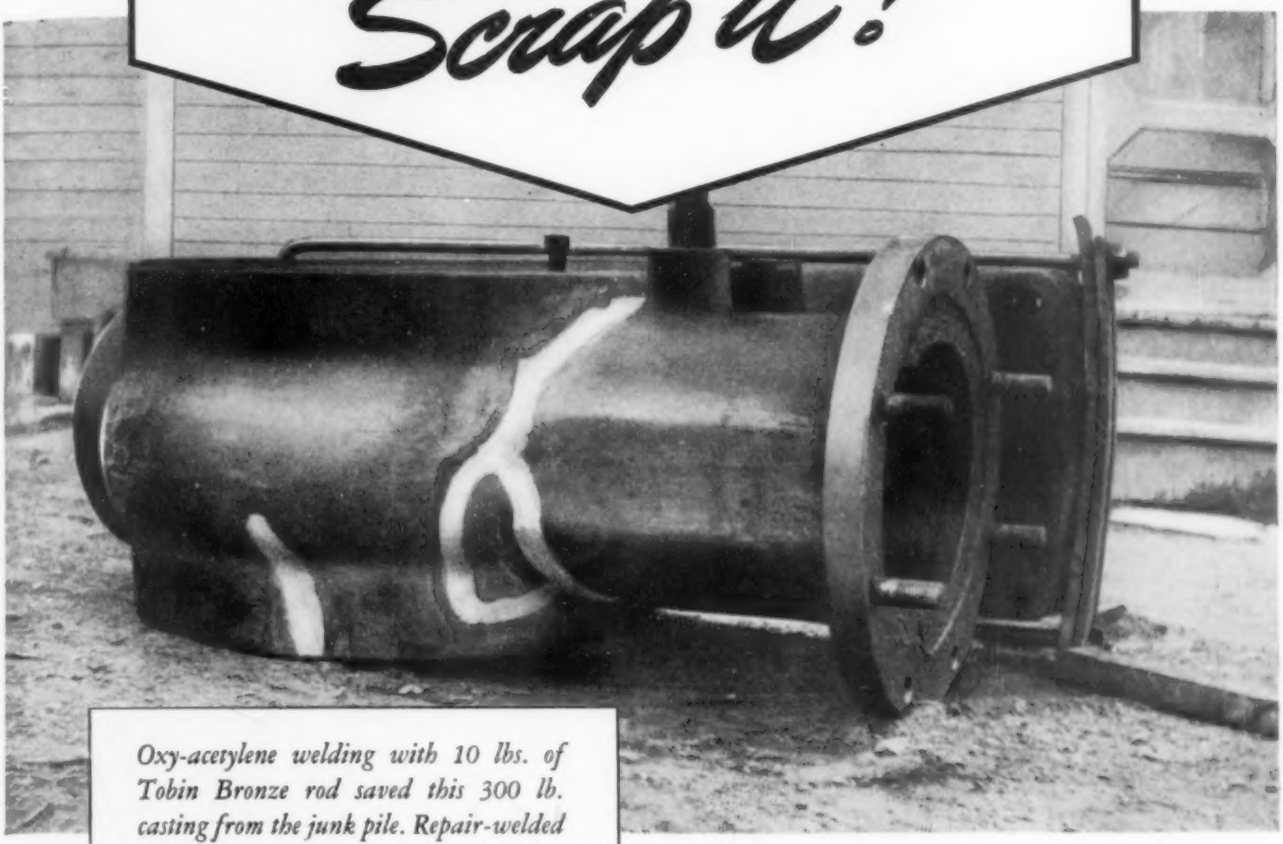
EFFICIENT

ECONOMICAL

FOR WELDING and CUTTING
Use National Carbide in the Red Drum
Lincoln Building NATIONAL CARBIDE CORPORATION New York, N. Y.

IN 1936—SOMEBODY SAID

"Scrap it!"



Oxy-acetylene welding with 10 lbs. of Tobin Bronze rod saved this 300 lb. casting from the junk pile. Repair-welded by Gemme Garage, St. Damase, Quebec.

But it was repair-welded with Tobin Bronze. Still going strong in December 1940!

When cracks appeared in the base of this crude-oil engine block, attempts to prevent their extension by clamps proved futile. In a short time they had practically encircled the cylinder —only fifteen inches of solid metal remaining between the ends of the cracks.

Replacement meant heavy cost and important time lost waiting for the new casting. It was then that Tobin Bronze welding was suggested. And just ten hours later, the engine base was ready to go back into service.

Every day similar cases demonstrate that expensive equipment, seemingly damaged beyond repair, can often be salvaged at nominal cost by welding with Tobin Bronze—a time-tried Anaconda product. The trademark "Tobin Bronze Reg. U. S. Pat. Off." is stamped in every rod. Look for it and be sure you get the genuine.

41188-A

ANACONDA from mine to consumer

Anaconda Welding Rods

THE AMERICAN BRASS COMPANY, General Offices: Waterbury, Connecticut

In Canada: Anaconda American Brass Ltd., New Toronto, Ont. • Subsidiary of Anaconda Copper Mining Company

made on a very simple formula. The specifications are not complicated. In fact, the biggest buyer in the world—Uncle Sam—has the simplest system of purchasing supplies, equipment and services. The system functions something like a large mail order house, except that where the latter sells to thousands, the government buys from thousands.

How can a business man sell to the government?

The initial venture of selling to the government will, of course, present some new problems. None of these problems, however, are necessarily complicated. In order to help manufacturers solve them, Jesse Jones, Secretary of Commerce, early in his administration set up a Service and Information Office, staffed with men who have had years of service in government and have recently completed months of intensive study of the purchase systems of each governmental office.

Consequently, the Service and Information Office is equipped to inform manufacturers whom they should contact and exactly how to do so. A manufacturer who desires to cooperate with the government in the present emergency, and lacks specific information as to how to proceed, is invited to apply to this unit, Room 1060, Department of Commerce, Washington, D. C. The effectiveness of the assistance rendered by the Office is demonstrated by the large number of telegrams and letters of appreciation which it has received.

Many manufacturers apparently have felt that if they desire to transact business with the government they must either come to Washington in person or employ somebody familiar with government purchasing methods.

The Service and Information Office strongly urges manufacturers not to come to Washington, at least until they have carried on preliminary negotiations by mail with the purchasing agency that handles their particular products.

They are advised not to employ outsiders on a commission or other basis. In fact, the War and Navy Departments and the Office of Production Management have repeatedly warned against the employment of what are termed "lobbyists" in the effort to obtain government contracts.

Furthermore, the Army, for example, has decentralized its purchasing system. Different depots specialize in purchasing specific supplies. Clothing is purchased in Philadelphia; shoes in Boston; various kinds of equipment in Jeffersonville, Ind.; aircraft supplies in Dayton, Ohio. A very small percentage of Army supplies is purchased in Washington.

The Navy, too, has part of its purchasing system decentralized and prefers to have preliminary negotiations conducted by mail. The Bureau of Supplies and Accounts purchases a major proportion of Navy supplies, aside from contracting for ships.

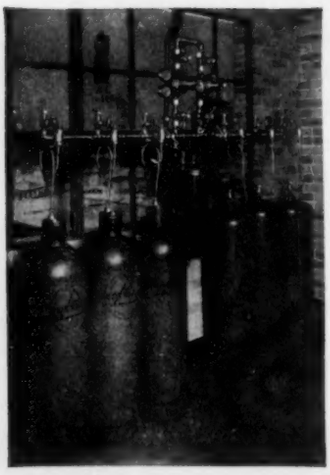
A third large purchasing agency of the government is the Procurement Office of the Treasury Department, a centralized purchasing agency for all departments except the Army and Navy. The Procurement Office also has branches in different parts of the country and prefers that preliminary negotiations be conducted by mail.

When it is necessary to come to Washington, the Service and Information Office will gladly arrange for the business man to see the particular official with whom contact should be made. In this way the business man will be able to get in and out of Washington with a minimum of time, effort and expense and return home with a clear understanding of the government's needs and the necessary procedure in helping to supply them. Generally, by following this suggested approach the business of the prospective contractor can be transacted in Washington within one or two days.

NAVY DEPARTMENT NEEDS MORE INSPECTORS

The *Inspector of Engineering Materials* positions pay from $1620 to $2600 a year and persons may qualify in the following optional branches: steel hulls, mechanical, electrical and radio. Although experience in the inspection or testing of engineering materials in the optional branches is required, applicants for the junior, assistant and associate grades will not be limited to any specific optional branch. Substitution of mechanical or other related types of experience, or of appropriate education, may be made for a part—or for some grades, all—of this inspectional experience. Except for the positions of junior inspector for which the maximum age is 35 years, applicants must not have passed their sixty-fifth birthday.

For SAFETY SPEED ECONOMY



MANIFOLDS
REGULATORS
VALVES and
FITTINGS
to control high pressure gases

REGO

The BASTIAN-BLESSING Co.
282 E. ONTARIO ST. CHICAGO

Pioneers and Manufacturers of Precision Equipment for Using and Controlling High Pressure Gases

The Design Engineer Says

"Fabrication with Mallory Standardized Welding Electrodes gives us leeway in design we never had before."

Dependable welds frequently contribute new latitude in design and function . . . and no factor has contributed more to dependable welds at lower cost than Mallory's program of standardization of welding electrodes.

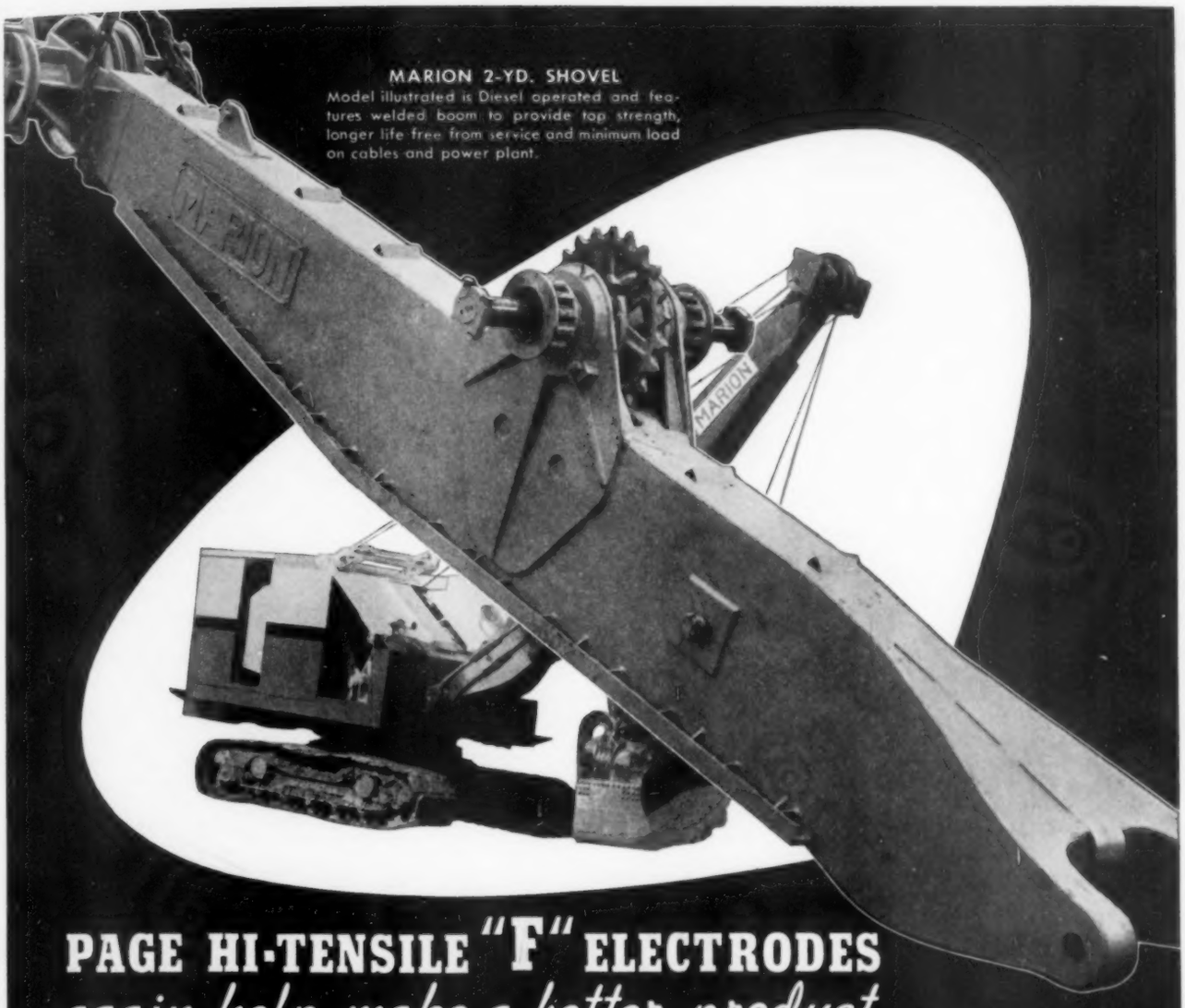
Proper cooling, hardness, design, electrical and thermal conductivity . . . the proper combination of these requirements has been determined to a degree that would be impossible without limitless field experience. As a result, Mallory Electrodes not only afford better welds . . . but provide more welds between redressing . . . and a far greater total number of welds before replacement is necessary. "Down time" against the completion of special orders is, of course, eliminated. Mallory Welding Electrodes are shipped out of stock.

Be sure to get all the details of Mallory's standardization program. It can result in many economies as well as a decided increase in efficiency.

MALLORY
Resistance Welding Data Book

Your engineers will find this complete technical reference invaluable. It covers all phases of resistance welding practices, alloys and specifications. Write for your copy today.

P. R. MALLORY & CO., Inc., Indianapolis, Indiana • Cable Address — PELMALLO



MARION 2-YD. SHOVEL
Model illustrated is Diesel operated and features welded boom to provide top strength, longer life free from service and minimum load on cables and power plant.

PAGE HI-TENSILE "F" ELECTRODES

again help make a better product

—LIGHTER and STRONGER

The 23-foot boom of this Marion Shovel is welded because Marion Engineers find the welded boom to be stronger, longer lasting and lighter in weight—qualities that are mighty important to the shovel operator.

But don't overlook the value of PAGE HI-TENSILE "F" Electrodes in this operation—permitting excellent speed with a minimum of spatter and slag loss and providing the smooth beads that good welders want to mark their work.

You, too, will find it worthwhile to ask your local PAGE Distributor to give you the facts about PAGE HI-TENSILE "F"—shield-arc type electrodes for horizontal, vertical or overhead welding.

Get this Free Booklet

Ask your local PAGE Distributor for a copy of this well illustrated booklet. It contains valuable information on 3-position shield-arc welding of carbon steels.

PAGE WELDING ELECTRODES

PAGE STEEL AND WIRE DIVISION • MONESSEN, PENNSYLVANIA

AMERICAN CHAIN & CABLE COMPANY, Inc.

Inspector of Ship Construction positions pay from $2000 to $2600 a year. There are four optional branches of inspection: electrical, mechanical, steel hulls and wood hulls. Experience in testing or inspection construction or installation work is required, but for a part—or for some positions, all—of this experience applicants may substitute mechanical or other related types of experience, appropriate education, or possession of a marine engineer's license. The maximum age limit is 65 years.

The duties to be performed by inspectors of engineering materials and ship construction involve testing and inspecting the type of marine construction, or construction materials, indicated by the optional branches. Inspectors will also read drawings and interpret specifications, as well as make inspection reports and conduct correspondence.

NEW BOOK ON WELDING INSTRUCTION

Lessons in Arc Welding, published by The Lincoln Electric Co., Cleveland, Ohio; 176 pages, 6 x 9 inches; 170 illustrations, including photos and drawings; cover—semi-flexible simulated leather, gold embossed; price 50 cents per copy, postpaid anywhere in U. S. A., 75 cents elsewhere.

Helpful to beginners learning to arc weld, also to experienced welders desiring its comprehensive practical information and to welding officials, such as supervisors, foremen and instructors, as well as others interested in the subject, the book comprises a ready reference on arc welding and a guide to its proper application. It will be found invaluable, at this time, to any industrial organization faced with the necessity of training its own welders to meet demands imposed by the National Defense Program.

X-RAY ANALYSIS IN INDUSTRY

The earliest application of X-ray analysis was to the determination of the atomic arrangement in crystalline structures, and this work has had far-reaching results in many branches of science. Of recent years this powerful tool of the physicist has been used to investigate many other characteristics of the solid state such as the identification of crystalline constituents of minute samples, the structure of alloys, the identification of intermediate products in chemical processes, the identification of allotropic changes in refractories and the determination of sub-microscopic crystal size and orientation. A new field, hardly explored at all as yet, is that of the sub-microscopic structures within each individual crystal, such as occur in age hardening and other types of imperfect phase precipitation in the solid state. Such structures profoundly influence physical properties and hence are of great interest.

The importance of this subject, particularly for the present war effort, has led to a widely expressed desire for closer collaboration and sharing of experience between those concerned with the subject. This desire is being met by the publication of a series of papers invited by Sir Lawrence Bragg, president of the Institute of Physics and a pioneer in this field, and will be published by the Institute in two special issues of the *Journal of Scientific Instruments* (which journal is now partly devoted to the applications of physics in industry). Each of these numbers will be enlarged to double the normal wartime size; the first group of papers will be published in the May issue and will deal with the applications of X-ray methods as applied to a wide range of industrial problems. The second group, which will appear two or three months later, will deal with the technique of the methods and some recent developments.

Copies of these special issues may be obtained from the Institute of Physics (temporary address: at The University, Reading, England), price 2*s.* 8*d.* each, post free, or from any bookseller. Early application for copies is advised owing to the limitation of paper supplies.

A SMALL PORTABLE CRUCIBLE FURNACE

An article on the above subject prepared by Prof. C. P. Philpot was published in the June JOURNAL, starting on page 382. Inadvertently, we omitted acknowledgment to the Hobart Brothers Company for furnishing us with this material.

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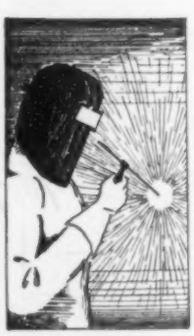

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ELECTRODES
FOR MILD STEEL
HORIZONTAL AND FLAT POSITION
TYPE W-24
SIZE 5/16" X 14"
350-450 AMP 30-36 VOLTS
USE DC STRAIGHT POLARITY or AC
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PRODUCTION DATA
This 50 lb. box of electrodes will produce 30.2 lb. of filler metal in joint, based on 2" stub ends.
Welding production is estimated as follows:
100 linear ft of 3/8" flat fillet welds
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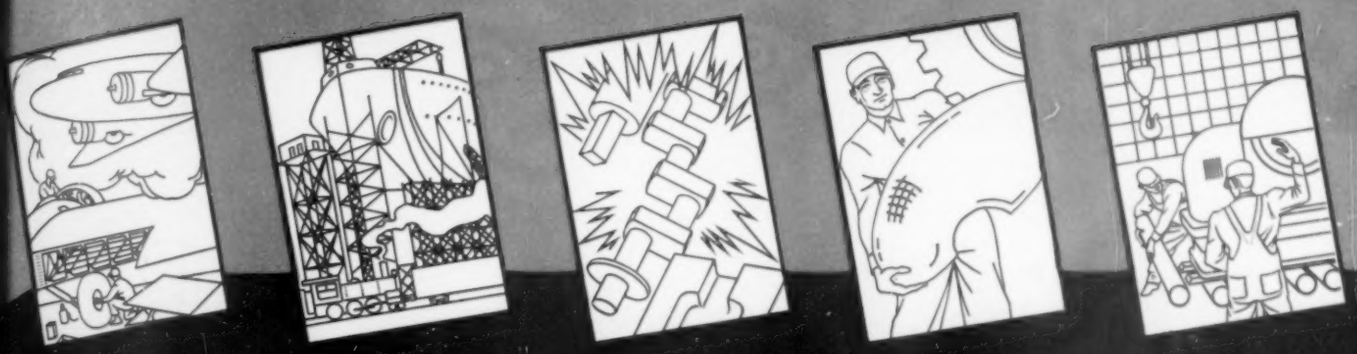
Production data is available on heavily-coated, mild-steel electrodes, "all-position" types, W-20, -22, -25, -30 (⅛- to ¼-in. dia.) and "flat-position" types, W-23 and W-24 (¼-in. to ⅜-in. dia.). Data on other sizes on request.

EVERY INDUSTRY



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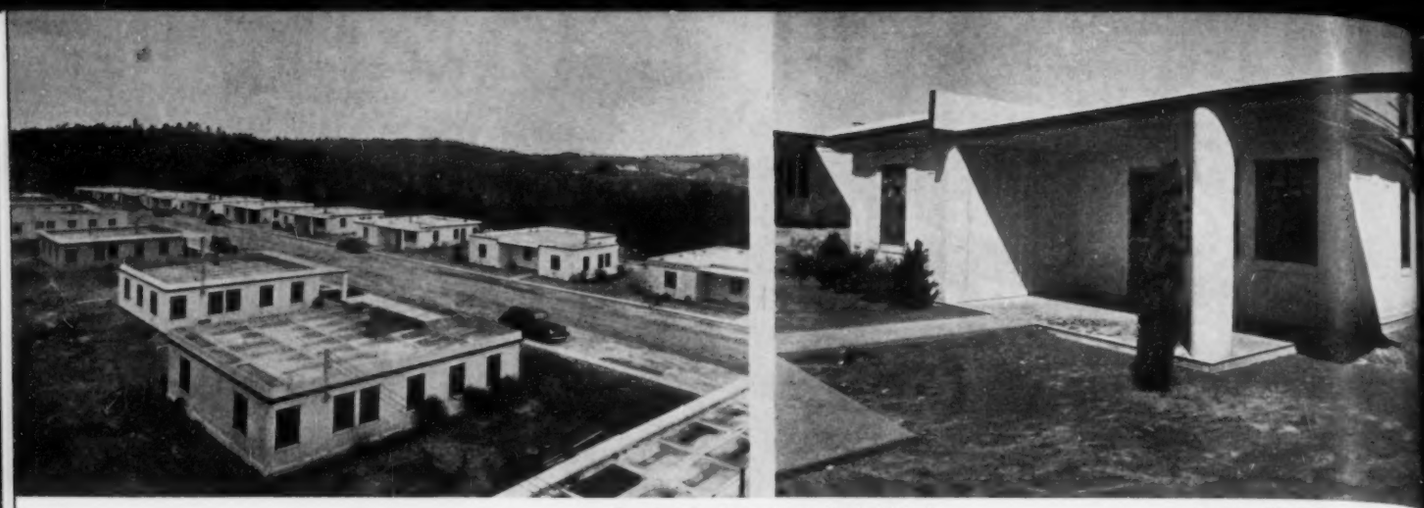

Housing Project of Arc Welded Steel *Courtesy Hobart Brothers Co.*

HOUSING PROJECT OF ARC-WELDED STEEL

A unique all arc-welded steel housing project for employees has been developed by the R. G. Le Tourneau Co. of Toccoa, Georgia. The project includes 52 employees' homes, hotel, dormitories, air port hangar, cafeteria, radio station and an office.

Employees' homes vary in size from five to nine rooms. The foundation and floors of the homes are made of concrete with "I" beams set into the concrete to provide for welding construction. The house is made up of panels of mild 12 gage steel pressed in a die to stiffen them so as to prevent warpage in welding and to improve the appearance of the finished panels. Each wall is of double construction so that Vermiculate may be blown between them for insulation. Windows are made of steel and welded into the casings. The only wood used in the entire house is in the doors.

The finished all-steel homes, equipped with sinks and lavatories, range in price from $2500 to $3000 depending upon the choice of furnishings.

G. E. DISTRICT ARC-WELDING REPRESENTATIVE

Frank C. Neal, Jr., has been appointed district arc-welding specialist for General Electric's Dallas district office, according to an announcement by C. I. MacGuffie, manager of electric welding sales. In this capacity, for the General Electric Company, Mr. Neal will cover the states of Texas, Oklahoma and part of Louisiana. He succeeds N. M. Voorhies who has been transferred to G-E's Chicago Office.

A graduate of Kansas University in 1936, Neal immediately became associated with General Electric in the testing department at Schenectady. In 1938 he was assigned to the International General Electric Company. The following year he joined G-E's welding section, handling application engineering and problems relating to welding. In this capacity he made extensive studies of factory welding production including automatic applications as well as both alternating and direct current welding.

As G-E's arc-welding specialist in the southwest, Mr. Neal's principal interest will be in the districts served by the B & A Welding Supply Company, Tyler, Texas; Briggs-Weaver Machinery Company, Dallas, Texas; Fort Worth Welding and Supply Company, Fort Worth, Texas; Hughes Welding and Supply Company, Shreveport, Louisiana; San Antonio Machine and Supply, San Antonio, Texas; and Wessendorf-Nelms and Company, Houston, Texas.

PRACTICAL SHIP PRODUCTION

By A. W. Carmichael. Formerly Commander, Construction Corps, U. S. Navy. Second edition, 283 pages, 6 x 9, 127 illustrations, $3.00.

Here is an ABC book of shipbuilding, written for the mechanic and technical man who wishes to enter this important and active industry or, already having a job in it, wants a quick, practical guide to details and methods of the work.

The book begins with the simplest form of a floating body, and, in developing its evolution into a modern ship, introduces requirements naturally that give the reader a practical understanding of special aspects of ship design and construction.

Description of the most important types of ships, and of the many different structural elements and parts of a ship, gives further groundwork for better understanding and handling of practical shipbuilding jobs, and helps the reader to "talk the language."

The building, launching and fitting out of a ship are fully described, both for a riveted and a welded ship. The practical methods of making molds and templates, fabricating parts, erection, etc., are explained in step-by-step detail. The subject of welding is covered fully because of the great increase in this type of ship construction.

EDUCATIONAL COURSES IN THE INTEREST OF NATIONAL DEFENSE

Secretary M. M. Kelly has been sending out to all Section Chairmen outlines of extension courses on welding at various institutions in the interest of national defense. The first series included the description of the courses at Ohio State University, George Washington University, Rensselaer Polytechnic Institute and Yale University.

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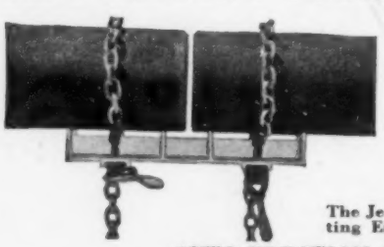

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Let us help you do away with costly, time-wasting shop experiments . . . show you new and practical short-cuts of greater economy and efficiency.

IT is our particular interest to help you predetermine the success of every difficult welding job you undertake. The first thing we do when we produce a steel is to study its welding qualifications and characteristics in order that we can recommend a definite range of its usefulness. For your protection, our experienced welding engineers determine just where and how the special steels we produce will best serve in all types of welding construction. And this specialized knowledge equips us to offer a service to the welding industry which we believe does more than anything else to take the *chance* out of welding construction.

If you have a problem — if you need help or advice in selecting steel that will fit into a particular type of construction—let us help you. Our experts stand ready to work with you at any time—without obligation. Call or write today for more complete information about the service they are capable of rendering.

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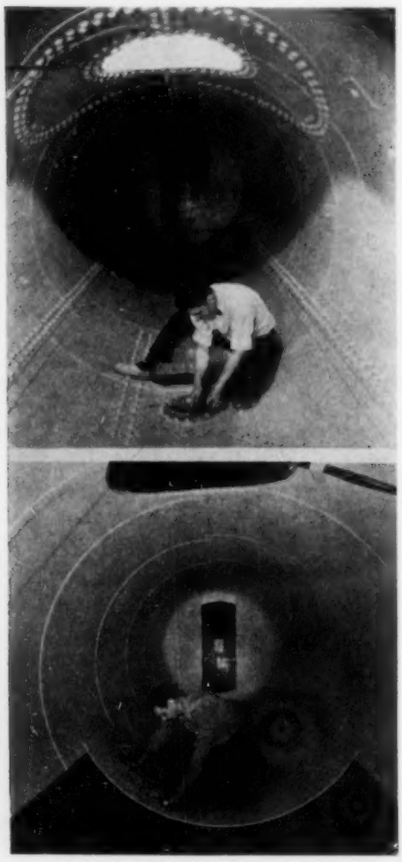
UNITED STATES STEEL

RUBBER LININGS

Improvement in the appearance and service life of the rubber linings installed in the new welded tank cars used by the chemical and allied industries, as well as a reduction in the cost of the linings, are pointed out by J. R. Hoover, manager of rubber-lined equipment sales of The B. F. Goodrich Company.



The photograph above shows one of these new welded tank cars in which rubber linings are being placed in The B. F. Goodrich factory in Akron, Ohio. The second picture shows the older-type riveted car in which the lining had to be formed over each rivet head.

Within the last several years there have been a number of welded cars built and equipped with rubber linings for tests. Official specifications (103BW) have only recently been issued by the Interstate Commerce Commission and the rubber-lined welded cars placed on the approved list.

HANDY & HARMAN OFFICERS

At the organization meeting of the Directors of Handy & Harman held April 29, 1941, the following officers were re-elected: Cortlandt W. Handy, Chairman; G. H. Niemeyer, President; R. H. Leach, Vice-President; H. W. Boynton, Treasurer; H. W. Spaulding, Secretary. Judson C. Travis continues as assistant to the president; R. F. Drew, manager Providence plant; F. L. Spies, manager New York plant. F. C. Jones, formerly assistant to J. C. Travis, was appointed manager of the Bridgeport, Conn., plant. J. L. Christie was appointed metallurgical manager. J. W. Colgan, manager of the Toronto, Canada, plant (subsidiary) will become sales manager of the parent company.

At the organization meeting of Handy & Harman of Canada, Ltd., held the same day, the following officers were re-elected: G. H. Niemeyer, President; R. H. Leach, Vice-President; H. W. Spaulding, Secretary-Treasurer. Thomas H. Gallagher, formerly in charge of the Chicago Sales Office of the parent company, was appointed Assistant Treasurer of the corporation and manager of the Toronto, Canada, plant.

NEW, IMPROVED BUYERS GUIDE FOR STEEL USERS

The 1941 Stock List recently published by Joseph T. Ryerson & Son, Inc., is the largest and most complete steel buyer's guide ever published by the company. New products, new analyses and new sizes plus an increased number of helpful charts and tables combine to make Ryerson's 268-page Stock List a most important addition to every steel buyer's reference file. In addition to a complete listing of all certified steel products carried in stock by Ryerson, the book contains S. A. E. standard specifications, a physical properties chart showing machinability of more than 50 steels, standard gage comparisons, weight tables and other helpful data.

SEES STEEL SHORTAGE CURBED BY WELDING

The anticipated shortage of steel which is being precipitated by the National Defense program will be much less acute if wastes of this vital metal by antiquated processes are stopped by utilization of modern methods of manufacture, fabrication and construction, according to The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

Figures just released by the Foundation show that an average of 18% less steel is required to build the welded product or structure than the same one riveted.

On this basis, production for National Defense would have 360 pounds more usable material in every ton of steel. Applied to the nation's annual ingot capacity of 82,000,000 tons, this would conserve $2^1/_2$ months' production each year.

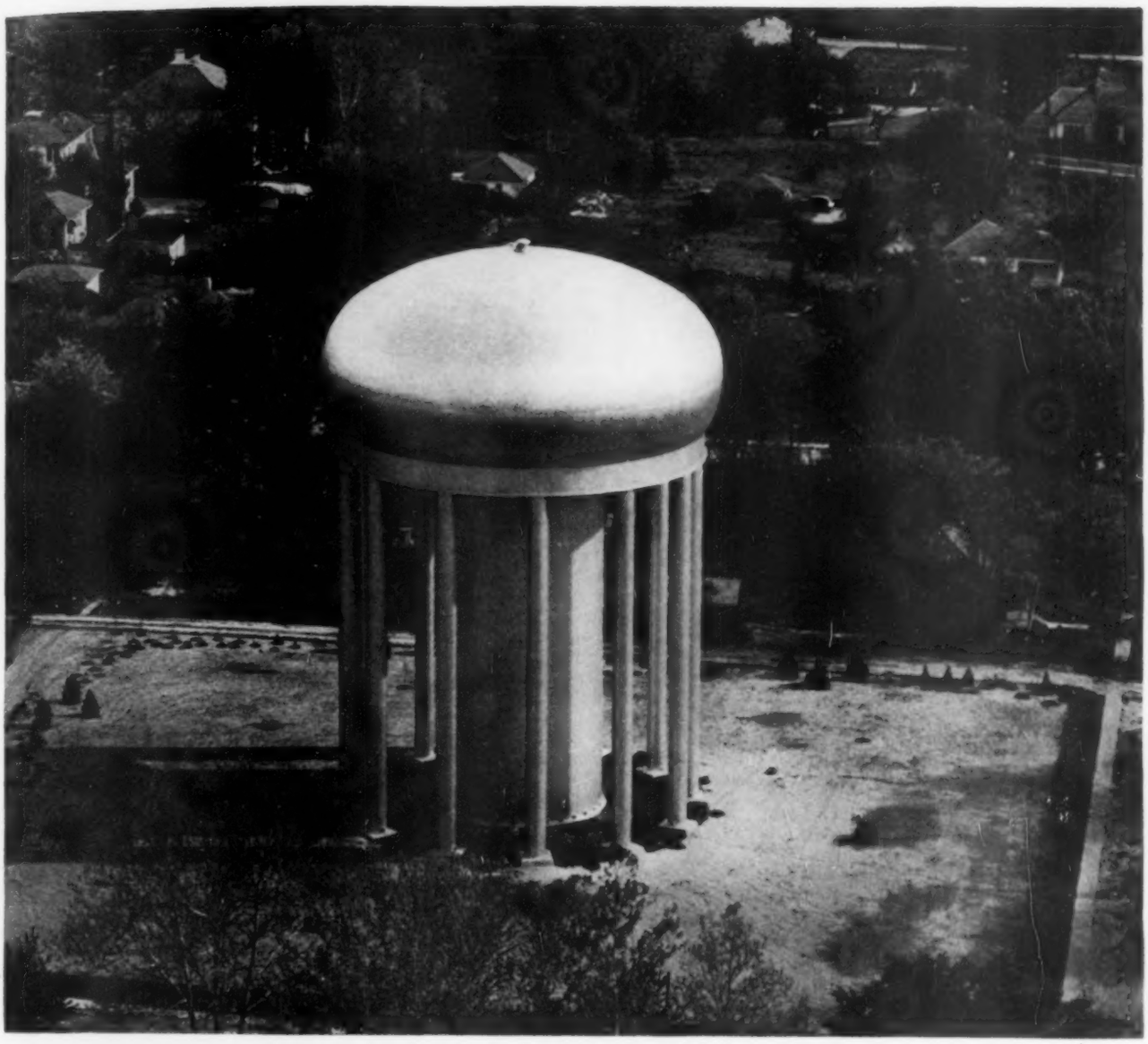
The actual percentage of steel savings in the Foundation's 15 case examples, which were taken at random from industrial reports, range from 9% on a field service truck body and freight car underframe up to 45% on a scroll case for a turbine (see table).

On the 10,490-pound freight car underframe, welded construction saved 1020 pounds, or sufficient to produce one *extra* underframe for every 10 frames produced.

Steel Saved by Use of Modern Welded Construction

Figures taken at random from industrial reports by executives, engineers, designers and others in active production

Product or Structure	Source of Data	Material Weights, Lbs. Riveted	Welded	Saved by Welding	Weight Saved, %
Field service truck body	Northwestern Electric Company, Portland, Ore.	2,158	1,958	200	9
House trailer	Trotwood Trailers, Inc., Trotwood, Ohio	2,920	2,174	746	25
Locomotive frame	Western Australian Government Railways, Midland Junction, Australia	24,769	17,942	6,827	27
Locomotive boiler	American Locomotive Corporation, Dunkirk, N. Y.	110,278	99,318	10,960	10
Barge	J. T. Dalcher, Consulting Engineer, New York City	565,000	500,000	65,000	11
Car float	Newport News Shipbuilding & Dry Dock Co., Newport News, Va.	1,976,290	1,666,860	309,430	15
Manufacturing plant building	Erie Steel Construction Company, Erie, Pa.	126,760	110,477	16,283	13
5-Span grider bridge	Geo. A. Fuller Co., New York City	1,597,088	1,175,563	421,525	26
Beach gear for large aircraft	Kenworth Motor Truck Corporation, Seattle, Wash.	17,610	14,258	3,352	19
Trailerized tank	The Heil Co., Milwaukee, Wisc.	7,640	6,550	1,090	14
Freight car underframe	The Ryan Car Co., Chicago, Ill.	10,490	9,470	1,020	9
Passenger coach frame	Madras & Southern Mahratta Rwy. Co., Park Town, India	94,000	65,000	29,000	31
Scroll case for turbine	Bureau of Reclamation, Denver, Colo.	391,640	214,830	176,810	45
Truck winch	Bay City Foundry & Machine Company, Bay City, Mich.	808	608	200	24
Mobile paving plant	Warren Northwest, Inc., Portland, Ore.	33,365	29,402	3,963	12



ELEVATED WATER TANKS

. . . of welded construction

Welding has played an important part in the building of elevated water tanks, particularly those of special design. It has enabled us to combine the spheroidal shape, used so extensively for oil storage tanks resting on the ground, with tubular columns to produce the streamlined structure shown above. It holds 1,000,000 gals. above an elevation of 70 ft. and provides gravity pressure in the water system at Jonesboro, Ark. Welding has also facilitated the building of spherical water tanks on single pedestals and other special designs.

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Cleveland	2282 Builder's Exchange Bldg.	Houston	918 Richmond Ave.	San Francisco	1097 Rialto Bldg.
Dallas	1489 Praetorian Bldg.	Detroit	1556 Lafayette Bldg.	Los Angeles	1471 Wm. Fox Bldg.

Fabricating plants in CHICAGO, BIRMINGHAM and GREENVILLE, PA.

SCOTT PAPER SHIP LAUNCHED

Here is the *Arthur Hoyt Scott*, first ship built for the Scott Paper Company of Chester, Pa., being launched in the Delaware River at the John H. Mathis & Co. shipyard in Camden. The vessel was christened by Mrs. Arthur Hoyt Scott, widow of the son of the company's founder in honor of whose memory the ship was named. The boat, the largest ever built in the Mathis yard, will carry bales of paper pulp between the company's mills at Nova Scotia and Brunswick, Ga., to the manufacturing plant at Chester.

The all-welded ship is 269 ft. long, has a beam of 42 ft. 6 in. and a cargo-carrying capacity of 3500 tons. President Thomas B. McCabe headed a delegation of company officials at the launching ceremonies.

GRAIN SIZE

Experiments just concluded by metallurgists at the National Bureau of Standards indicate that there is no relation between grain size and toughness of steel, the Department of Commerce announced today.

Knowing that it would be highly advantageous if the important property of toughness in steels could be correlated with some other easily ascertained characteristic, Samuel J. Rosenberg and Daniel H. Gagon made a series of notched bar tests of a medium carbon forging steel at different degrees of heat. The tests were made so as to have different grain sizes in the specimens used.

The results show that each individual heat of a medium carbon forging steel has an inherent resistance to impact peculiar to that particular heat, and that this impact resistance is dependent upon factors not at present recognized.

It was found that as the specimens were hot rolled no relation existed between grain size and toughness, and that all the steels were quite brittle. Normalizing—heating to 1600° F. and air cooling—caused some improvement in toughness. When so treated the fine-grained steels were tougher than the coarse-grained steels.

Proper heat treatment—hardening and tempering—resulted in a marked improvement in the toughness of the steels, but in this condition there was no relation between grain size and toughness.

Thus, it is apparently not possible to correlate the effect of grain size and heat treatment with the impact-toughness of steel. However, it is known that most steels lose toughness—become brittle—quite rapidly as the temperature is decreased. The range of temperature wherein this change occurs is a reliable criterion of the relative toughness of steels—the lower the temperature at which toughness is lost, the better the steel.

ALL-WELDED TRAINING QUARTERS FOR CIVILIAN SOLDIERS

Crack welders recently set about the construction of an all-welded apprentice building for the Harnischfeger Corporation of Milwaukee, and with the number of plant employees at an all-time high, the need for young men well trained in the skills of the metal trades was urgent. Pioneers in the welded construction of giant cranes and shovels, the company naturally turned to welding as the fastest and most efficient method of constructing the apprentice building.

The photos below show the construction at an early stage and at completion. The main channel steel forms, welded while

Fig. 1

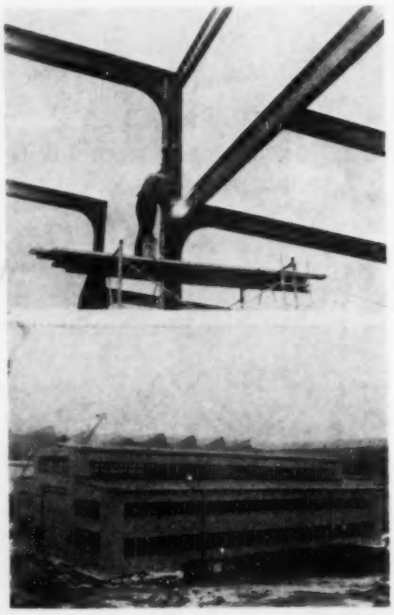
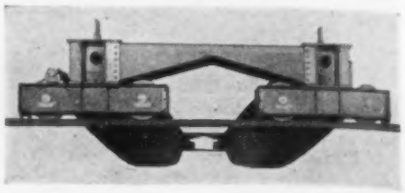


Fig. 2

on the ground, were positioned with cranes and then welded to cross members. Work progressed rapidly and soon the framework was completed and ready for the prefabricated steel panels. In an amazingly short time the building was ready for its 100 eager trainees who were to learn the machinists' trades. Well ventilated, flooded with light from broad window areas, the building is a striking example of the speed and effectiveness that can result when welding methods are applied to factory units of this type.

HEAVY-CAPACITY CRANE

For large heavy-capacity cranes of the type used for power houses and other moderate services, requiring eight bridge track wheels, The Cleveland Crane and Engineering Company, Wickliffe, Ohio, has developed a novel crane end tie which is extremely simple in design.



The tie is made of one heavy rolled steel plate that is first cut to shape and then bent to form a box section. Bending is done "cold" on a Steelweld bending press. Into the box section are welded reinforcing diaphragms to effect the rigidity required.

This end tie construction is known as a "spring type," since it has sufficient give or spring to allow all wheels to bear properly on the track at all times, despite runway irregularities.

The picture shows the end tie of a 100-ton 90 ft. 0 in. span Cleveland Crane.

TRUSSES FOR WELDED SCHOOL BUILDING WEIGH 19 TONS EACH

In the construction of the steel work for the recently completed Benjamin Franklin High School in New York City, arc welding reduced the cost and facilitated the provision of clearances required by architectural design. All shop fabrication and all important field connections were welded.

For example, there were four trusses about 58 feet in length required to span a small gymnasium. All four of these trusses were a full story in depth and two of them weighed 19 tons each. In Fig. 1 there is a good close-up view of one of these larger trusses. Its general location with relation to the main building can be seen in Fig. 2, which is an assembly view of the building. The small gymnasium is at the back of the south wing which appears at the right of the assembly photograph, taken soon after erection of this wing was started. A large

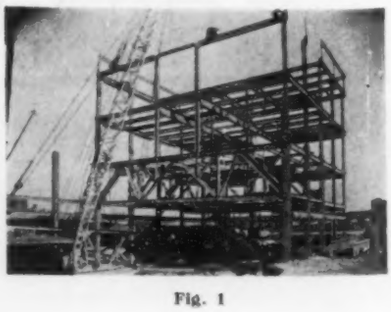


Fig. 1

ALWAYS CONSIDER RESISTANCE WELDING

Front view of a Federal Welder being used by aircraft industry mechanics to weld a fuselage bulkhead.

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Federal research engineers with complete facilities are constantly forging ahead, providing new principles and improved design to broaden the field of resistance welding. New developments of today are the accepted practices of tomorrow. Federal will help you keep pace with fabricating progress by the most modern, time-saving methods.

The Federal Uni-Pulse method, heretofore applied to spot welding aluminum alloys, is now available for use in roller spot welding . . . ANOTHER MAJOR DEVELOPMENT PIONEERED BY FEDERAL. As in Uni-Pulse spot welding, this improved method employs electrostatic storage of energy and greatly reduces peak power demands, at the same time providing flexible control of the current wave form, fully explained in Technical Bulletin No. 527. Federal Roller Spot Welding, utilizing the advantages of Uni-Pulse design, speeds up production in the manufacture of military aircraft and other products demanding fabrication of aluminum alloys.

Send for Technical Bulletin No. 527. Additional up-to-the-minute information may be obtained through any Federal Branch Office or Factory Representative.

THE Federal MACHINE AND WELDER COMPANY WARREN, OHIO

SALES OFFICES IN ALL PRINCIPAL CITIES

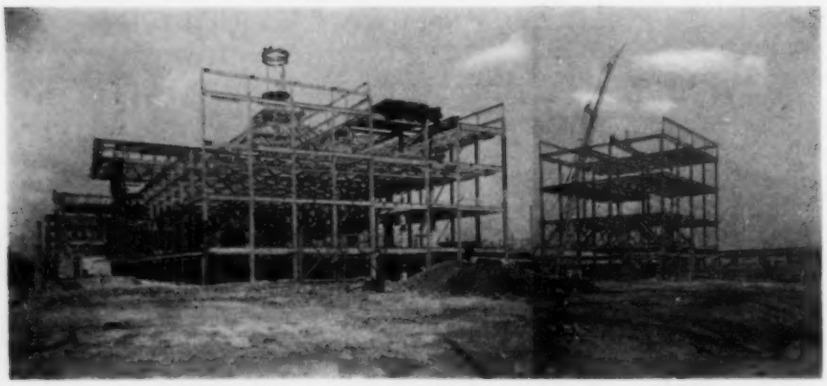


Fig. 2 *Courtesy Air Reduction Sales Co.*

gymnasium and an auditorium at the front of the building are spanned by 79-foot 13-ton welded trusses.

AIRCO IN THE NEWS

We offer our congratulations to the Air Reduction Sales Company in connection with the publication of Volume 1, No. 1, of "Airco in the News." The first number is unusually attractive. It is a thorough representation of Arc Welding and Gas Cutting in industry and particularly defense work. This publication is to appear bimonthly for "a better understanding of the scope of the oxyacetylene flame and the electric arc as production, repair and maintenance tools." Answers to any questions concerning the use of any of these processes or products will be furnished by writing to the editor, G. T. Van Alstyne, Air Reduction, 60 East 42nd St., New York City.

UNION CARBIDE AND CARBON CORP.

An unusually interesting series of articles on the growth and development of the Union Carbide and Carbon Corporation appears in the current issues of *Fortune*. We strongly advise all our readers to read this series.

A. S. T. E. SETS UP CURRICULUM FOR COLLEGE COURSE IN TOOL ENGINEERING

Details of a proposed general curriculum for college courses in Tool Engineering were released recently by the National Educational Committee, American Society of Tool Engineers.

The curriculum which is already under consideration by several universities and engineering colleges is designed to place the science of Tool Engineering on the same fundamental basis as Mechanical, Civil and Electrical Engineering, etc.

Lack of availability of such courses in the past has been largely responsible for the shortage in Tool Engineers to expedite the National Defense Program.

A relatively recent "profession," Tool Engineering is an outgrowth of the evolution of mass production. Tool Engineers are the men who are responsible for taking drawings and blueprints of parts and determining how and on what kind of machines and with what tools those parts should be produced. Most of today's Tool Engineers are virtually self-trained and most of them have come up the long hard way—through the "shop."

The new college course in Tool Engineering comprises four years of study. It differs from the average conventional engineering course in that there is a considerably closer tie-up between theoretical studies and practical problems in industry.

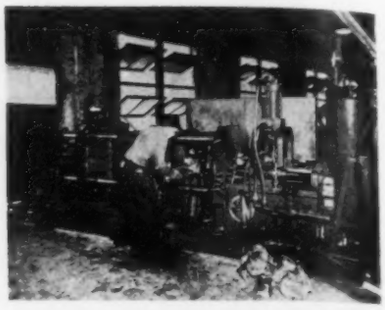
Included in the course are such "normal" subjects as: Chemistry, Algebra, English, drafting, trigonometry, analytic and descriptive geometry, elementary surveying, calculus, electricity, mechanics, economics, accounting, dynamics, physical education, etc.

In addition there are courses in: military science, forging, heat treating, welding, materials of engineering, foundry practice and pattern making, principles of metallography, elementary and advanced machine shop practice, cost accounting, metallography of special alloy steels, time and motion study, machine shop equipment, jig and fixture design, finishing processes, wages and compensation, production control, materials handling, die design, cost and production estimating, budgets and planning, resistance welding, and maintenance and millwrighting, etc.

The college course thus for the first time is designed to give the graduate a working knowledge of virtually all the factors entering into the profession of Tool Engineering.

ALL-WELDED DIECASTING MACHINE SPEEDS DEFENSE WORK

All-welded diecasting machines sufficiently strong and rigid to make sound castings with little "flash" on high-speed production schedules are now in successful production at the G. & N. Manufacturing Company, Cleveland, Ohio. These machines, designed for casting of zinc, lead, tin, aluminum, brass and magnesium alloys, employ massive steel-welded construction in the base, cylinder mounting, cylinder head, furnace, hydraulic fluid tank, short cylinder and goose-neck support. Only a few bolts and stud fastenings are used throughout the machine. Die plates of 6-inch thickness and 4-inch tie bars running through them preclude the possibility of breakage and assure a rigid machine.



Courtesy Hobart Bros. Co.

The machine pictured above is a G. & N. diecasting machine employed with three hydraulic core pullers which work cores in three different directions. These automatic core pullers permit extremely fast operation of the machine. When making small simple castings without cores or complex parts and using automatic ejection, the machine may be operated at a speed of 600 cycles per hour. Due to the extremely strong construction of this machine, it has been found to operate satisfactorily at rates 20 to 30 per cent faster than those usually practiced.

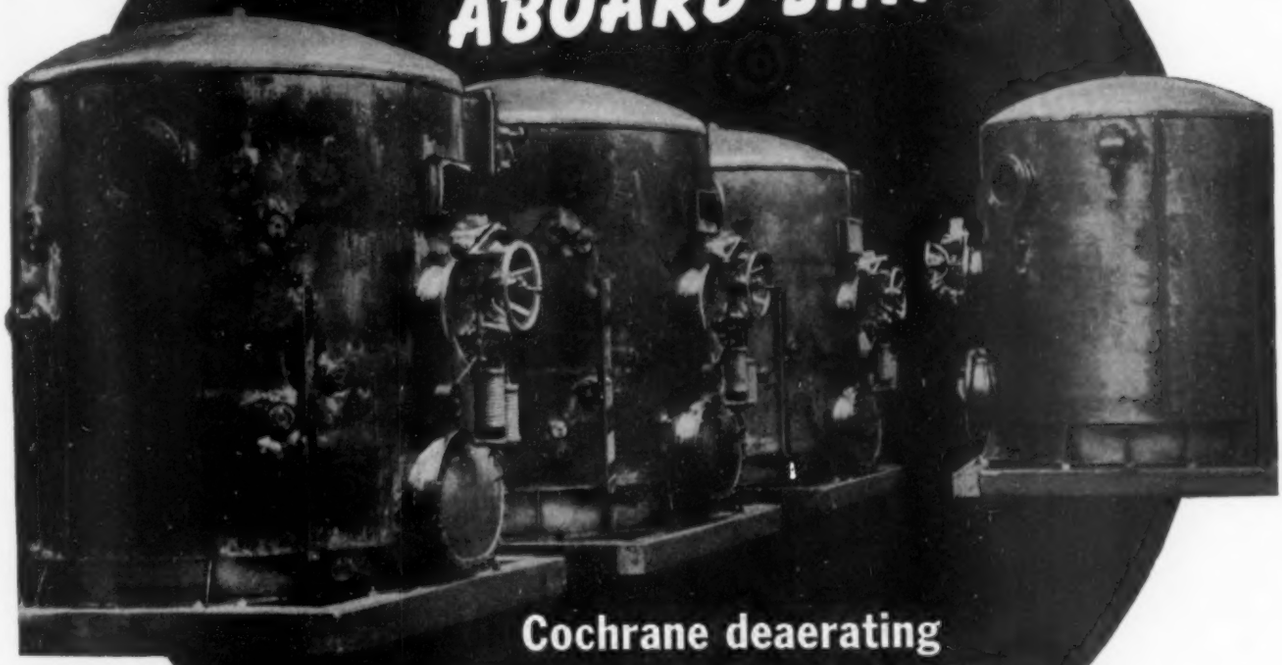
HARD-FACING PLOW SHARES

Two new sales promotion folders describing the advantages of hard-facing plow shares are now available from Haynes Stellite Company for distribution by welding shops to farmers. These folders, "Longer Life for Your Plow Shares with Haystellite Tube Rod" (Form 4739) and "Longer Life for Your Farm Implements with Haynes Stellite Alloy" (Form 4967), tell how plowing costs are reduced by hard-facing plow shares with these two rods. A list of other farm implements which can be hard-faced is also included. These folders are useful in arousing farmers' interest in the advantages of hard-facing and in the services welding shops are prepared to furnish. Both folders are of "envelope-stuffer" size, so that they can be inserted in standard envelopes to accompany correspondence or bills. Copies of these folders, imprinted with the welding shop's name and address, can be obtained without charge by writing to Haynes Stellite Company, Kokomo, Indiana.

ELECTRODE IDENTIFICATION

Arcos Corporation, manufacturers of electrodes for welding stainless steels and alloys, announces the publication of a new stub end identification color chart. The color designations listed on this chart are in accordance with the recently adopted N. E. M. A. Standards. A copy will be sent upon request. Simply address Arcos Corporation, 401 North Broad Street, Philadelphia, Pennsylvania.

FOR MINIMUM WEIGHT ABOARD SHIP...



Cochrane deaerating heaters welded with No. 130X Monel arc welding rod

Deaerating feed water heaters made of Monel by Cochrane Corporation, Philadelphia, Pa., of welded construction, employing No. 130X Monel arc welding rod.

TYPICAL of welded Monel* construction, are these Cochrane deaerating feed water heaters. Used in ships of the navy and merchant marine, they protect feed piping, economizers, and steel boiler tubes against corrosion.

These units, made of Monel, are of welded construction, employing No. 130X Monel arc welding rod.

Monel, Nickel, Inconel* and Nickel-clad steel, widely used in equipment building for defense, are readily welded. Which rods and fluxes to use? Refer to the box at right. Write also for complete working instructions. Address:

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York, N. Y.

INCO WELDING RODS and FLUXES

MONEL

Oxy-Acetylene . . . No. 40 Monel Gas Welding Rod — Monel Gas Welding Flux.
Metal Arc . . . No. 130X Monel Metal Arc Welding Rod.

NICKEL

Oxy-Acetylene . . . No. 41 Nickel Gas Welding Rod — no flux is used.
Metal Arc . . . No. 131 Nickel Metal Arc Welding Rod.

INCONEL

Oxy-Acetylene . . . No. 42 Inconel Gas Welding Rod — Inconel Gas Welding Flux.
Metal Arc . . . No. 132 Inconel Metal Arc Welding Rod.

NICKEL-CLAD STEEL

Metal Arc . . . No. 131 Nickel Metal Arc Welding Rod.

INCO MONEL

*"Monel" and other trade-marks which have an asterisk associated with them are trade-marks of The International Nickel Company, Inc.

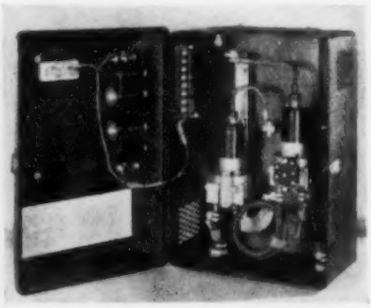
NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

NEW 150-AMPERE WELD-O-TROL

For use with timing facilities as used in spot welders, a new electronic welding contactor is announced by Westinghouse Electric and Manufacturing Company.

Known as the SW 150 Weld-O-Trol, this unit, for spot-welding applications, is rated equivalent to a size 2-W mechanical contactor at 220 or 440 volts, 50/60 cycles. Welding current is handled at extremely high rate of interruption by two heavy-duty water-cooled ignitron tubes. The tubes are held by water-



cooled clamps made of copper tubing cast in heat-conducting alloy. Provisions are made for removal of tubes without disturbing the water connections. A thermostat mounted on the cooling clamps protects the tubes against high temperatures caused by failure in the water supply.

All auxiliary control is mounted inside the Weld-O-Trol steel cabinet door to permit accessibility and yet allow physical separation from the power circuit. Ample space is provided for power and control leads.

The unit is readily adapted for use with heat control and either synchronous or non-synchronous weld timers including sequencing equipment.

PORTABLE ACETYLENE GENERATOR

A new portable acetylene generator for use in oxyacetylene welding and cutting has just been announced by The Linde Air Products Company, a Unit of Union Carbide and Carbon Corporation. This generator, known as the Oxweld MP-10, will deliver 30 cu. ft. of acetylene per hour and is suitable for welding metal up to $^3/_8$ in. thick, and for cutting steel up to 5 in. thick. It is designed for maximum portability, from a standpoint of weight and height, and can readily be moved about the shop or away from the shop for outside jobs. The generator can be recharged speedily, and is simple and easy to operate.

Generation of acetylene is started, set for regular operation, and stopped, by rotating the single pair of operating handles at the top of the generator. Once the operating handles have been set, generation of acetylene proceeds automatically.

The pressure of acetylene delivered to the blowpipe is controlled by a regulator which forms an integral part of the generator, and a separate pressure gage indicates at all times the pressure within the generating chamber.

Other construction features of the MP-10 generator include two relief valves which automatically vent any excessive pressures that should develop within the generator or in the delivery hose, and a hydraulic back-pressure valve which, by providing a water seal between the hose and generator, prevents any reverse flow of gas.

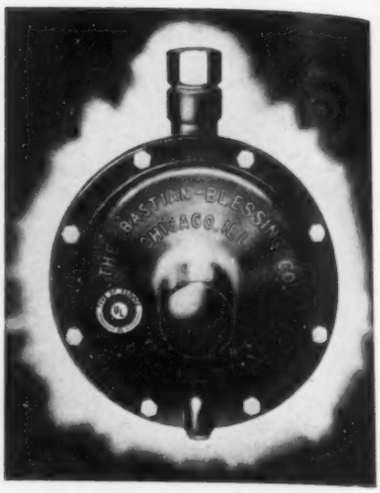
The MP-10 is strongly constructed of welded steel parts. It weighs only 100 lb. when empty and 250 lb. when charged, and measures only 3 ft. $2^1/_2$ in. in height.

GAS REGULATOR

The Bastian-Blessing Company, Chicago, is introducing its new RegO No. 2503 LP Gas Regulator which is designed primarily for heavy load conditions. This is an addition to the RegO line of regulators and does not replace any of the present types.

A somewhat different design principle is embodied in this regulator so as to permit relatively large capacities without an appreciable increase in the size of the regulator.

The effective diaphragm area and lever ratio have been selected to give the best



possible operation over the normal range of inlet pressure and load conditions. The RegO No. 2503 Regulator is equipped with a safety relief valve built in as an integral part of the main diaphragm.

MIDGET FLEXARC WELDER—WT-1

For use in welding light-gage metal castings and drive shafts, general maintenance and light production work, a new Flexarc welder is announced by Westinghouse Electric and Manufacturing Company.

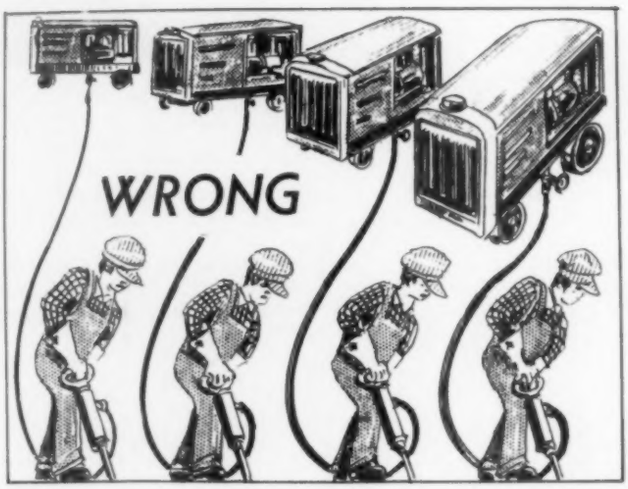
Known as the Midget Marvel WT-1, this a-c welder comes complete with all accessories, even to the primary cable for hooking up the power line. Included in the accessories are electrode lead and holder, work lead, helmet and a supply of electrodes.

Fig. 1—New Westinghouse Midget Marvel WT-1 Welder Showing the Disconnect Switch Primary Cable and 3-Prong Polarized Plug Attached

Sensitive adjustment of the welding current over a range from 20 to 140 amperes is provided by 15 steps with correctly proportioned increments between steps. Full load rating is 110 amperes, 30 minutes, 30 load volts, when used on 220-volt, 60-cycle lines. The cost of power consumption averages about 5 cents an hour depending on local power rate.

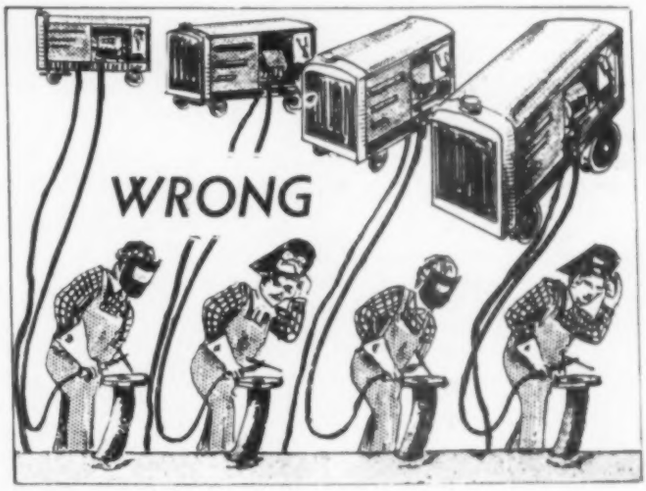
The unit is very compact. Approximate dimensions are $14^1/_2$ x $12^1/_8$ x 20 inches long. Weighing only 160 lb., the welder is supported on castors to facilitate mobility.

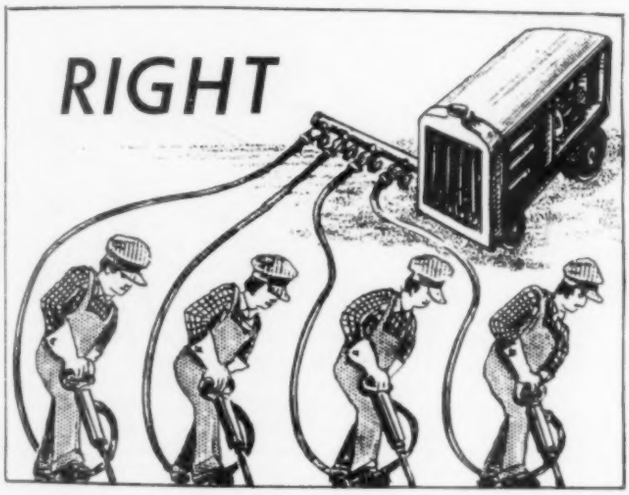
A PARA DOX LLEL

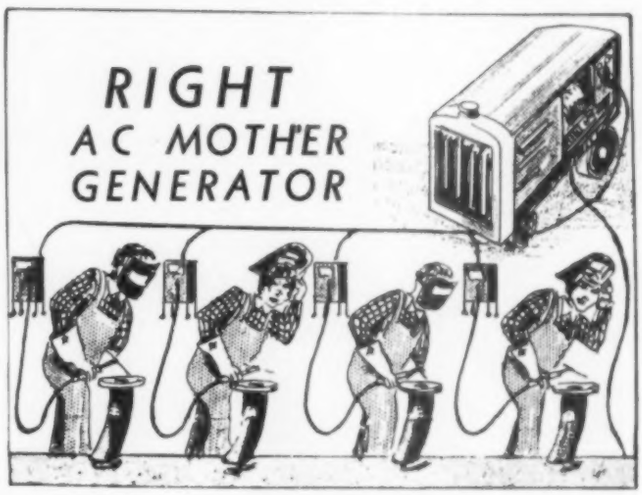


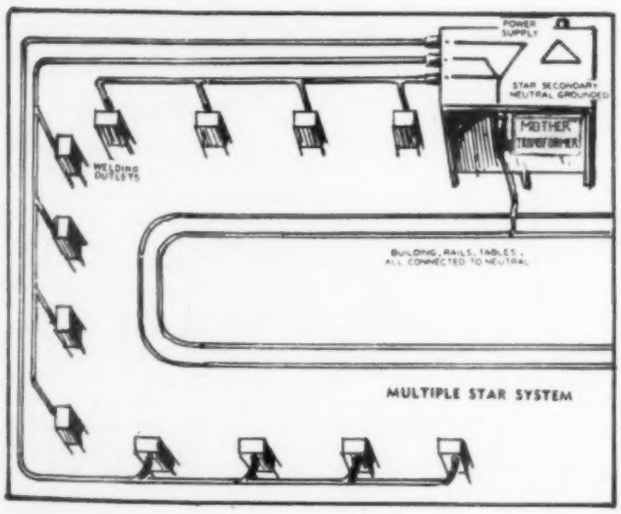
Of course not! You would not provide four separate units for four operators . . . with WELDING GENERATORS as well as with AIR COMPRESSORS you would install only one MOTHER UNIT with only one engineer to pay.

The multiple star system AC Welding functions electrically on the same principle as an air compressor supplying operators through a reservoir or a water tank behind the fire sprinklers.









THE ANALOGY IS APPARENT!

FOR WORK IN THE FIELD WE MAKE GAS OR DIESEL DRIVEN WELDING GENERATORS. FOR STATIONARY SHOP USE, A MOTHER TRANSFORMER WITH ONE WELDING LEAD TO SUB-OUTLETS IS REQUIRED. OF COURSE THERE ARE MANY OTHER ADVANTAGES FOUND WHEN USING THE MULTIPLE STAR SYSTEM. POWER IS REDUCED, SPEED AND WELDING IMPROVED.

ELECTRIC ARC, INC.

152-162 JELLIFF AVENUE, NEWARK, NEW JERSEY

CUTTING ATTACHMENT

The low-priced RegO KXA attachment has these features:

1. Its increased body length of 12 in., plus an extra long high-pressure lever, results in better operating control and better balance.

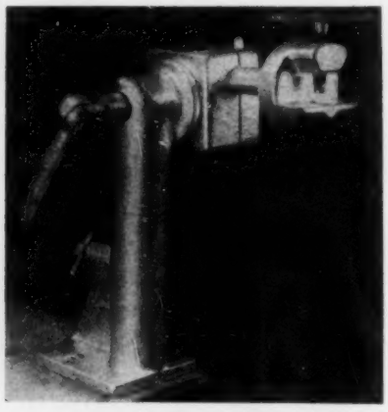
2. Leak-proof, high-pressure oxygen valve action results from the RegO diaphragm, which replaces the packing used in ordinary construction.

3. Hard, non-warping, forged-alloy head withstands terrific heat developed in heavy cutting and is abrasion-resistant to prolong life of threads and seats.

Write National Cylinder Gas Company, 205 West Wacker Drive, Chicago, Illinois.

WELDING JIG

The new Stoody welding jig, which can easily be adjusted to any desired position, makes it possible for the operator to hard-face almost any type of small equipment (such as farm tools) with the least possible time and effort and, in addition, is so sturdily constructed and so accurately machined that it will last a lifetime. All parts of the jig, with the exception of the bolt, adjusting screws and heavy duty spring (which incidentally is recessed into the head and well protected) are made of cast iron—eliminating any danger of the working parts "freezing" when the jig becomes hot.



Prices and more detailed information may be obtained from any Stoody distributor or Stoody Company, Whittier, Calif.

HOSE REELS

A new line of Hose Reels, that have been under development and test for several years, are now being manufactured by the M & H Hose Reel Company, 5202 Alhambra Ave., Los Angeles, California.

M & H Hose Reels employ a different principle to turn the reel for rewinding the hose than has previously been used on self rewinding reels. A coil spring enclosed in a cylinder actuates the reel through a gear drive.

M & H builds a reel especially for gas welding and cutting service. A parallel twin hose is carried on a single reel and a special guide roller prevents twisting or tangling of the hose. Two self-sealing rotary ball bearing joints are incorporated in the design, thereby eliminating intermixture of gases as well as the packing gland problem.

These single and twin hose reels have many applications in manufacturing plants, machine shops, plate and sheet metal fabricating plants, garages, etc., for such services as welding, cutting, blow guns, air tools, air hoists, liquid dispensing, paint spraying and many other uses.

LENSES

The ability of a new-type, non-shattering material, used in Tulca lenses, to make production equipment stay in service longer is shown in this comparative picture. Actual flash-welding service proved

that tempered glass lenses, shown at left, began to pit after only one hour of use—and became so pitted, after 16 hours of service, that they had to be replaced. Under the very same flash-welding service conditions, Tulca lenses, shown at right, resisted pitting by sparks and hot metallic particles—and were still in excellent condition after more than 100 hours of use. Tulca lenses are a recent development of The Univis Lens Company, of Dayton, Ohio.

DEDICATING AUSTIN BUILDING

Several hundred members of The Austin Company's Cleveland organization, together with their families, joined Saturday, May 24th, in dedicating the company's new engineering building at 16112 Euclid Avenue to the memory of Wilber J. Austin, president of the national engineering and construction organization from 1924 until his death last December.

Standing in the paneled entrance lobby alongside a photomural which reviews 63 years of Austin progress, Mrs. Ida S. Austin unveiled a dedication plaque presented by fellow workers in grateful appreciation of her husband's "vision and leadership in industrial research and building design."

The ceremony followed brief talks in the modern engineering quarters, where efficient working space for 100 engineers has been provided beneath a series of 70-foot welded rigid frame arches.

Austin Engineering Building—Dedicated to the Memory of Wilber J. Austin "in Grateful Appreciation of his Vision and Leadership in Industrial Research and Building Design."

George A. Bryant, now Austin president, reviewed Mr. Austin's contribution to the company founded by his father, Samuel Austin, an English carpenter's apprentice who emigrated to Cleveland and took up his trade here in 1872.

WELDED TRAIN

The "keel laying" of the new Empire State Express was celebrated at the Budd plant July 14th as F. E. Williamson, president of the New York Central, and Edward G. Budd, president of the Budd Company, made the first weld in the center sill of the first of the 32 streamlined cars under construction for the New York-Buffalo luxury flyer.

A throng of railroad operating executives, newsmen and others interested in the progress and development of railroading attended the ceremony, said to be the first "keel laying" ever held for a railroad train. First of the cars will be completed within three weeks, with delivery of the completed train scheduled for early fall.

Inauguration of the new streamliners—one will be operated each way daily—will celebrate the 50th year of operation of the famed "Empire." To run on the fastest daylight schedule between New York, Buffalo and the Mid-West, the trains will consist of tavern cars, parlor cars, chair coaches, dining cars and observation lounge cars and will represent the last word in modern design and luxury.

Employment Service Bulletin

SERVICES AVAILABLE

A-413. Welder. Just completed 44 hours' course at the General Electric Arc Welding School. Can weld in flat, vertical and overhead positions. 25 years of age, 5 ft. 9 in. tall.

A-414. Welder, foreman, inspector, former shop owner. Fifteen years' experience as Electric or Acetylene welder on structural steel, plate and pipe work, Manganese, Aluminum, Copper and Nickel. Passed Navy, Hartford and A. S. M. E. Tests. Can read prints and estimate. Single, first-class physical condition. Can go anywhere. References. Wants position where hard work would get advancement.

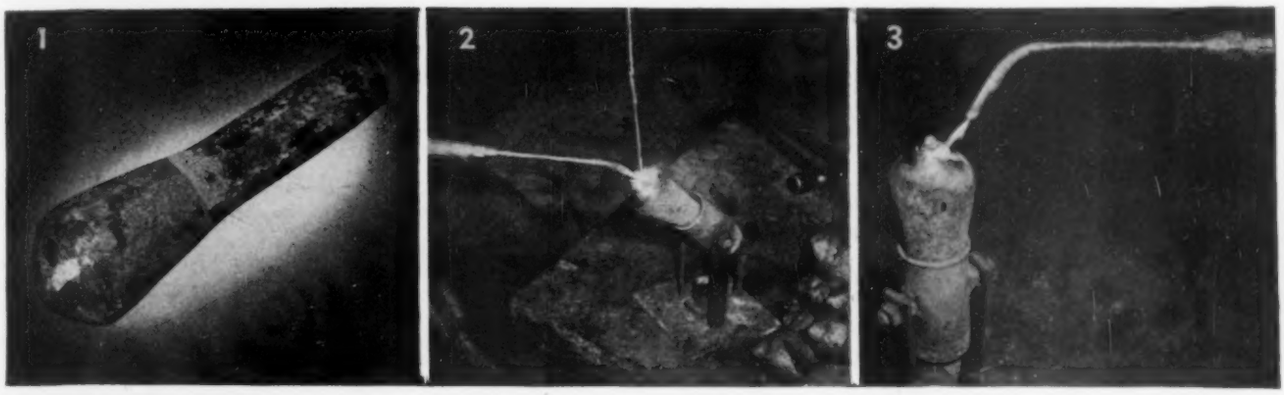
STANDARDIZE YOUR HARD-FACING...

Use Haynes Stellite Products for Longer Life—

-a rod for every purpose- and practical field men to help you make every application profitable.

HAYNES STELLITE hard-facing alloy — noted for its resistance to abrasion, heat, and corrosion —increases the life of wearing parts from 3 to 10 times, resulting in substantial savings in replacement costs. In addition, the longer life means lower maintenance costs and less shutdown time for changes.

Haynes Stellite alloy is being used *profitably* on wearing parts in practically every industry. Haynes Stellite Company has a rod for every type of hard-facing application, and—equally important—has experienced sales engineers who will give you practical assistance in the design of hard-faced parts and the selection and proper application of the most suitable hard-facing rod. Call on us, without obligation.



Simple Jig Speeds Hard-Facing of Ingot Tong Bits

The jig shown in the pictures above was developed for hard-facing crane tong bits used in lifting red hot ingots from soaking pits. The use of this simple jig makes it easier for the welder to handle these bits and speeds up the application of the hard-facing rod.

The life of these tong bits was increased several times by hard-facing them with Haynes Stellite No. 12 rod as follows: the worn bit was ground to remove scale and slag (Fig. 1)—then preheated in a gas furnace. With the hot bit placed in the adjustable jig at an angle most convenient to the operator (Fig. 2), about ¼ lb. of rod was applied to build up the end, which was then shaped to a point with the blowpipe (Fig. 3).

* * *

Hard-facing can save you time and money. Phone or write Haynes Stellite Company—"Headquarters for Hard-Facing Materials."

HAYNES STELLITE TRADE MARK

HAYNES STELLITE COMPANY

Unit of Union Carbide and Carbon Corporation

New York, N. Y. UCC Kokomo, Indiana

District Offices: Chicago, Cleveland, Detroit, Houston, Los Angeles, New York, San Francisco, Tulsa.

RED-HARD, WEAR-RESISTING ALLOY OF COBALT, CHROMIUM, AND TUNGSTEN.

"Haynes Stellite" is a registered trade-mark of Haynes Stellite Company

SECTION ACTIVITIES

BOSTON

The Chairmen of the several committees of the Boston Section for the year 1941–42 are as follows:

New and Delinquent Members Committee, W. D. Strathdee; *By-Laws Committee*, H. A. Sweet; *Meetings and Papers Committee*, P. E. Kyle.

The latter committee is preparing the program of meetings for the coming season, and has planned to announce the meetings for the entire season prior to the first meeting in October.

CHATTANOOGA

Mr. R. B. Bayston was elected Chairman and Mr. M. R. McLain, Secretary-Treasurer of the Chattanooga Section, for the coming year, at a banquet and social gathering of the Section held on June 20th. This was the only business transacted at this meeting. A most enjoyable evening took place at this get-together which was the last meeting until the fall.

CINCINNATI

At the Annual Election of the Cincinnati Section held on June 18th, the following officers were elected for the coming season:

Chairman: Wm. A. Maddux, Cincinnati Milling Machine Co.; *Vice-Chairman:* L. B. Blakeney, Westinghouse Elec. & Mfg Co.; *Treasurer:* R. G. Fugate, Williams and Co., Inc.; *Secretary:* R. L. Kirby, Hobart Bros. Co.; *Newly elected members of the Executive Committee:* Eric O'Hara, Robt. Emmons, A. E. Taylor.

The Cincinnati Section has had a very successful series of lectures and they wish to thank the various companies which sent their representatives to give lectures for the benefit of the Section.

DETROIT

At a meeting of the Executive Committee held at the Detroit Leland Hotel, June 30th, it was decided to hold nine meetings during the 1941–42 season. All are scheduled to be held the evening of the first Friday of the month beginning September 5, 1941, and ending May 1, 1942, with a Ladies Night. The January meeting will be held on the second Friday, January 9, 1942. Joint meetings will be discussed with other technical societies.

The following committee chairmen were appointed:

Membership, C. F. Flynn; *Meetings and Papers*, W. H. Hayes; *Publicity*, W. F. Sherman; *Educational*, A. H. Lewis.

NEW YORK

The appointment of committees and the development of plans for the regular meetings and lecture course for the coming season were the principal items of business at the first meeting of the Executive Committee of the New York Section which was held on July 1st at the Engineering Societies Building.

J. G. McGrath was appointed by E. V. David, newly elected Chairman of the New York Section, to serve as Chairman of the Program Committee. Plans call for eight regular technical meetings during the 1941–42 season, four of which are tentatively scheduled as joint meetings with the American Society of Mechanical Engineers, the American Society of Civil Engineers, the American Society of Naval Architects and Marine Engineers and the American Society for Metals. Starting with September, meetings will be held the second Tuesday of each month, with the exception of October, when no meeting is scheduled because of the Annual Meeting in Philadelphia. Other members appointed to serve on the Program Committee are A. K. Seemann, R. E. Bedworth, G. W. Place and T. R. Higgins.

The Lecture Course which has been held under the sponsorship of the New York Section the last few years at Polytechnic Institute of Brooklyn, and which has proved so successful, will be continued again this year with E. Vom Steeg, Jr., as Chairman. Ten sessions have been planned, with each lecture scheduled to be presented by authors of chapters of *The Welding Handbook*, the new edition of which is now in preparation. Assisting Chairman Vom Steeg on the Lecture Course Committee are Wm. Spraragen, G. Schneider, W. A. Howard, C. Kandel, H. R. Morrison, O. T. Barnett, A. K. Lindquist and Prof. O. H. Henry.

Other committees appointed by Chairman David are as follows: *Membership Committee*—E. A. Kerbey, Chairman, Wm. Spraragen, and G. Schneider; *By-Laws Committee*—J. T. Phillips, Chairman, Miss M. M. Kelly, W. A. Howard and G. V. Slottman; *Finance Committee*—E. V. David, Chairman, George Sykes, J. G. McGrath, G. Schneider and E. A. Kerbey.

PITTSBURGH

The following officers were elected to serve the Pittsburgh Section during the 1941–42 season:

Chairman, A. E. Marble, Carnegie-Illinois Steel Corp.; *Vice-Chairman*, C. H. Jennings, Westinghouse Elec. & Mfg. Co.; *Secretary*, J. F. Minnotte, Minnotte Brothers Co.; *Executive Committee:* G. O. Hoglund, W. H. Kauffman, C. P. Streithof.

The new officers will be inducted into office at the opening meeting in October.

WESTERN NEW YORK

A special meeting of the Executive Board was held June 13, to talk over plans for the coming season and to arrange the summer activities of the section.

We are sorry to announce that the Section Secretary, Don Patterson, has again met with an accident—which will keep him in the hospital for many weeks with a broken hip. It was a fall from a barn roof this time.

A general outline of next winter's meetings was set up. It is planned to have another extensive membership drive and a preliminary list of names was given to the membership committee. John Bos and Jim Murray were appointed to arrange a golf party for July 18th and it is hoped that sufficient members will come to make this an annual affair.

List of New Members

June 1 to June 30, 1941

BIRMINGHAM

Mann, George C. (C), 709 S. 21st St., Birmingham, Ala.

CANAL ZONE

Walters, Lester O. (D), 10th Signal Co., Ft. Clayton, Canal Zone.

CINCINNATI

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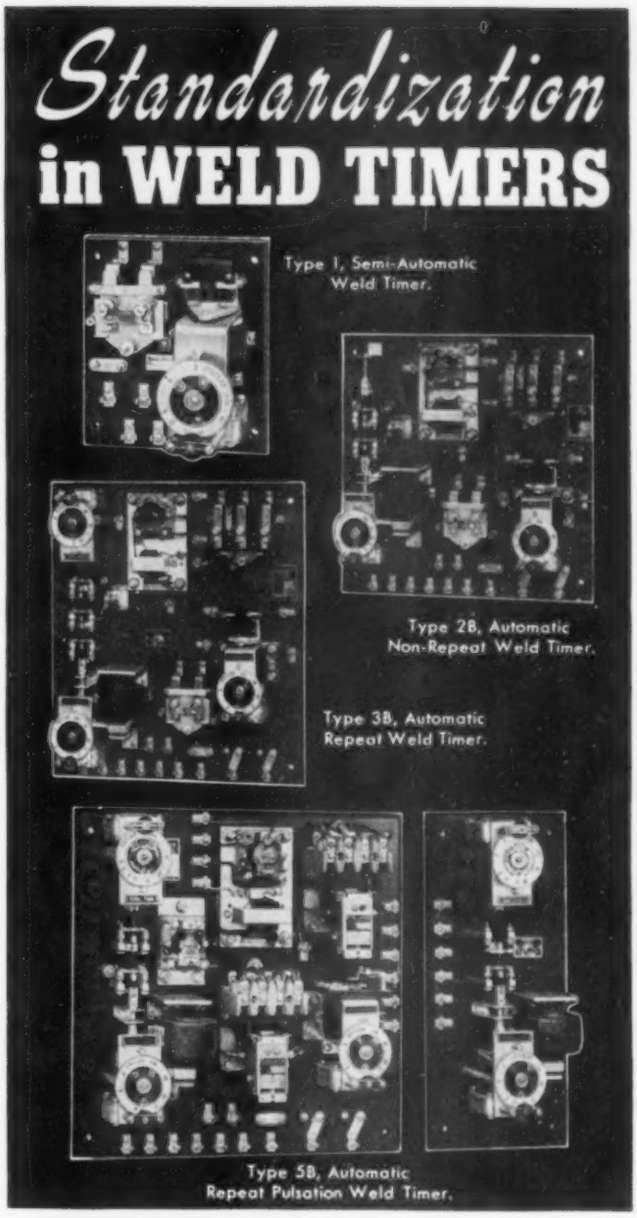
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One of the first million-volt industrial x-ray units ever built is being installed by Combustion Engineering Company in its Chattanooga boiler shops. The development of an industrial unit of this rating was initially announced by the General Electric Company in December 1940, when they dedicated the installation at Schenectady of the pioneer million-volt industrial unit, as part of the program commemorating the 40th anniversary of the G-E research laboratory.

The unit for Combustion Engineering, built by the General Electric X-Ray Corporation, exceeds by 600,000 volts the rating of the largest previous industrial units. It is capable of radiographing 8-in. steel in good commercial time and will effect a tremendous reduction in the time required for radiography of welded seams of the usual thickness required in boiler drums and other high-pressure vessels. The walls of the drums for modern high-pressure boilers range in thickness from about 3 in. to 5 in. or more. The new unit will radiograph 5-in.-thick plate in about 5 minutes at a focal distance of 48 in., and 3-in. plate at the same focal distance can be penetrated in 48 seconds. With the 400,000-volt unit, the most practical focal distance for these thicknesses is 32 in., and at this distance the exposure time for the corresponding thicknesses are: 5-in. plate—135 min.; 3-in. plate—$2^1/_2$ min.

Thus a twofold time saving will be effected—the reduction in exposure time which increases rapidly with metal thickness (more than 100 times as fast at $5^1/_2$ in.) and reduction in number of negatives because of the longer focal distance which can be used. The importance of the latter results from the large number of exposures required to radiograph the seams of big drums—several hundred per boiler in some cases—and the time consumed in setting-up for each exposure. Another important advantage is the superior quality of the negatives obtained which provide a wealth of sharp diagnostic detail even at maximum penetration.

METAL & THERMIT BUILDS NEW RESEARCH LABORATORY

Continuing to expand its research and development activities, the Metal & Thermit Corporation, New York, N. Y., started the construction, on July 1st, of a new research laboratory at Rahway and Randolph Avenues, Woodbridge, N. J.

The front section of the building will house administrative offices, library and analytical laboratories, as well as the chemical laboratories of the Ceramics and Detinning departments of the corporation. Two wings at the rear will be occupied by laboratories devoted to research on arc welding electrodes, Thermit welding and Thermit metals and alloys, while a third wing will contain process and manufacturing development divisions.

Research activities of the Metal & Thermit Corporation are under the direction of Dr. Lincoln T. Work, formerly of Columbia University.

METAL SPRAYING

Defense demands for metal conservation, as well as the shortage in machine tools and skilled labor, have placed new emphasis—not to say new value—on the Metallizing process. To help answer the flood of questions arising from this new stimulated interest, Metallizing Company of America, Inc., 562 West Washington Boulevard, Chicago, Illinois, has published a book, "The History, Purpose and Practice of Metallizing."

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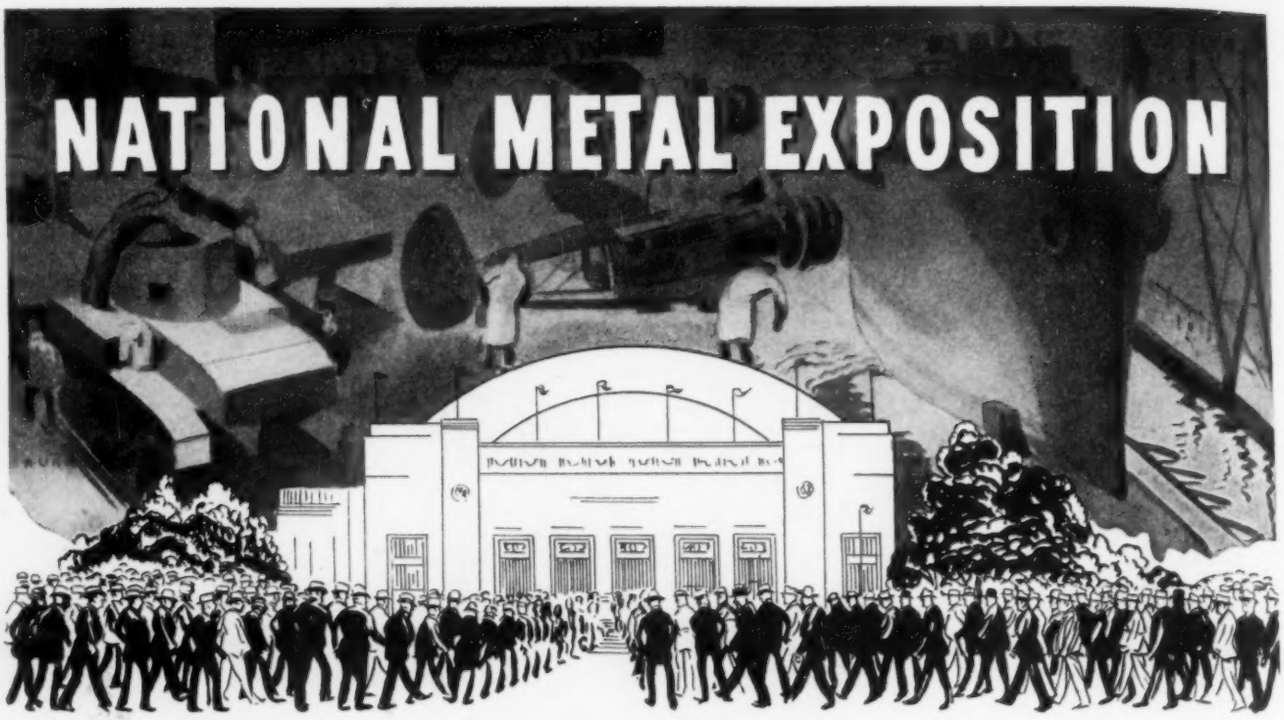

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Secretary